Frontispiece]

Illustration No. 1. Young Sisal plantation.

E.M.B. 10

EMPIRE GROWN SISAL

and its Importance to the Cordage Manufacturer

MEMORANDUM

prepared by

THE IMPERIAL INSTITUTE

with the co-operation of its Advisory Committee on Vegetable Fibres,

Great Britain

and issued by

THE EMPIRE MARKETING BOARD

OCTOBER, 1928

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller.

1928.

Price *6d.* Net.

70-221-10.

Increasing supplies of Sisal are now becoming available in East Africa and other parts of the British Empire, and the attention of manufacturers is called to this source of supply, especially in view of the demonstrated suitability of the fibre for marine cordage in addition to its other well-known uses.

(33636) Wt. P1225/457/757 5,000 10/28 Harrow G.3

INTRODUCTION.

THE increasing popularity of Sisal has been an outstanding feature of British cordage manufacture during the present century. This fibre although originally derived from a plant indigenous to Mexico has proved superior to the so-called "henequen," produced in large quantities in the latter country, which is obtained mainly from a distinct but allied species. The object of the present pamphlet is to indicate the nature of the Sisal plant, the properties of the fibre and the remarkable developments which have taken place during recent years in its production in countries of the British Empire. It is hoped that it may arouse an increased interest in the fibre among cordage manufacturers.

Great changes have taken place during the last hundred years in the manufacture of cordage. At one time the chief and almost the only fibre employed for the purpose in this country was hemp (*i.e.* true hemp, the fibre derived from the stalks of *Cannabis sativa*), but subsequently this was largely replaced by Manila hemp, which in turn has more recently found a competitor in Sisal and to a smaller extent in New Zealand hemp (phormium fibre) and Mauritius hemp. True hemp is a non-lignified fibre, possessing a character which leads to its inclusion in the class of "soft fibres"; the other products are more or less lignified and belong to the category of "hard fibres."

The relative extent to which the different hard fibres are utilised in the United Kingdom is indicated in the following table which gives the imports from the principal countries of origin for the years 1924–1927.

Fibre.	*Country whence consigned.*	1924.	1925.	1926.	1927.	*Average annual imports.*
		tons.	*tons.*	*tons.*	*tons.*	*tons.*
Manila Hemp ..	Philippine Islands	63,459	55,629	40,822	50,063	52,493
Sisal	British East Africa	6,811	8,870	6,230	7,027	7,234
	Portuguese East Africa	961	1,234	729	208	783
	British West Africa	123	166	362	263	229
	Dutch East Indies	219	629	407	332	397
Henequen	Mexico	885	45	47	702	420
Mauritius Hemp ..	Mauritius	176	716	1,357	509	690
New Zealand Hemp .. (Phormium Fibre)	New Zealand ..	4,684	7,222	7,421	7,620	6,737
	St. Helena ..	690	784	814	715	751

Illustration No. 2. Sisal plants, 3 years old.

From these figures it is evident that of the hard fibres, Manila hemp is imported in much larger quantities than any other. This product is chiefly used for the manufacture of cordage and is at present produced almost exclusively in the Philippine Islands.

New Zealand hemp or phormium fibre first came into use in this country 100 years ago, but was not obtained in large commercial quantities until about 1866 after machinery had been invented for producing the fibre rapidly from the green leaf.

Mauritius hemp, derived from the leaves of *Furcraea gigantea,* a plant belonging to the same natural order as the agaves from which Sisal and henequen are obtained, first became an article of commerce about the year 1875.

Henequen or " Mexican Sisal " is extracted from the leaves of certain species of Agave and mainly from those of *Agave fourcroydes* Lam. (*A. rigida* Miller var. *elongata* Jacobi), which is known locally as " Sac-ci." The production of this fibre constitutes the principal industry of the State of Yucatan. The first attempt to produce Mexican Henequen on a commercial scale was made in 1839. The cost of preparation by hand, however, was so high as to be discouraging and the industry failed to expand greatly until the invention of a machine (the so-called " raspador ") for extracting the fibre. Most of the fibre is exported to the United States where it is employed for the manufacture of binder twine. Thus in 1919 of the total quantity exported from Mexico over 99 per cent. entered the United States. Serious endeavours are now being made to extend the market to other countries and it is estimated that about 3,000 tons have recently been sold in Great Britain. Henequen fibre is usually more brittle and less flexible than East African Sisal, is neither so white nor so well cleaned and is also less regular. This last difference is probably due to the fact that the plantations in Yucatan are composed of mixed species, whereas in East Africa it may be said that one definite strain only is grown which would naturally lead to uniformity of the product. As mentioned later this strain was introduced from a few plants originally derived from Mexico. Mexican henequen is usually quoted in the market at a price about 10 per cent. below that of East African Sisal of No. 1 grade.

The only other hard fibre of commercial importance is that known as Sisal which is derived from the leaves of *Agave sisalana* Perr. (*A. rigida* Miller var. *sisalana*). This plant is a native of Central

America and has been introduced into most tropical countries of both hemispheres. The development of the Sisal-growing industry in the British Empire is an outcome of enterprise carried out during comparatively recent times. The industry, which has progressed at a phenomenal rate, has now assumed large proportions especially in East Africa, and is still continuing to expand. The fibre is now being grown in commercial quantities in the British possessions of Kenya, Nyasaland, Gold Coast, Ceylon, Bahamas and Jamaica, and also in the Mandated Territory of Tanganyika.

It has already been shown that Manila hemp is at present imported into the United Kingdom in much greater quantities than any other hard fibre and is largely used for the manufacture of cordage. There appears to have been a general impression among users of marine cordage that Manila hemp is better suited for this purpose than Sisal, it having been alleged that the latter fibre is unable to withstand the action of sea-water. An investigation was therefore undertaken by the Imperial Institute with the object of determining definitely the effect of sea-water on the strength and durability of Sisal in comparison with Manila hemp. In these experiments three similar ropes, made respectively of 1st and 2nd quality British East African Sisal and Manila hemp of the J grade, were exposed under identical conditions to the action of sea-water. The tensile strength of the ropes was determined before the commencement of the experiments and after 4 months', 6 months', 9 months' and 12 months' exposure to the sea-water. The results showed that at each stage of the trial the 1st quality Sisal rope had suffered less deterioration than the Manila rope and had thus withstood the action of sea-water throughout the year better than the latter. In general, the trials indicated that Sisal is not inferior to Manila in its resistance to the action of sea-water and that, when exposed under the same conditions, they deteriorate at approximately the same rate. The test also showed that Sisal rope when immersed in water appears to swell rather more than Manila rope and also sinks more rapidly.

Illustration No. 3. Sisal plants, 4 years old.

Height of man 6 feet.

CULTIVATION & PREPARATION OF SISAL.

Before proceeding to trace the development of Sisal growing in countries of the British Empire, it may be of interest to consider briefly the nature of the plant from which the fibre is derived, the methods employed in propagating and cultivating it, the mode of harvesting the leaves and extracting the fibre, and the yields obtainable.

The Sisal agave has a short trunk bearing a number of dark green, thick, fleshy leaves ranging from four to six feet in length and from about four to six inches in width at the base ; each leaf is terminated by a long, sharp thorn. The plant flowers only once during its life ; the age at which this occurs varies in different regions and appears to depend largely on the climatic and soil conditions. The flowering stem arises from the centre of the plant as a thick " pole " which rapidly grows to a height of 20 to 30 feet. Small, whitish, waxy-looking flowers are produced in dense clusters at the ends of short, slender lateral branches of the pole and, after they have begun to wither, buds arise in the axils of the flower-stalks. From these buds arise hundreds of small plants known as " bulbils " which grow to the length of a few inches and then fall to the ground where, under suitable conditions, they take root. After the production of the bulbils, the whole plant withers and dies.

Another characteristic of the Sisal plant is the production of underground stems or rhizomes. These arise from the main stem or trunk and, after a short growth, make an effort to bud and produce leaves. When these leaves succeed in pushing their way up through the soil into the air, the bud gives rise to a new plant or sucker.

In order to develop satisfactorily, the Sisal plant demands a tropical climate with moderate atmospheric humidity. It is very hardy but is liable to be adversely affected by excessive rain. Sisal is capable of growing on rough dry soils which are unsuitable for most other crops but flourishes best on a dry, permeable sandy loam, containing a fair proportion of lime. Although the production of fibre is favoured by periods of drought, these periods must not

be of such duration as to reduce the plant's vitality to any serious extent. In East Africa the conditions are very favourable owing to the occurrence of two rainy seasons each year and in this respect they are greatly superior to those of such countries as Mexico where the plant is subjected to prolonged drought. It is essential that the land should be well drained as the roots of the plants are sensitive to moisture and are liable to be seriously injured by standing water.

In preparing the land for Sisal planting, trees and scrub must be removed, and stumps should be uprooted in order that an even surface may be obtained. In Tanganyika and on the coast-lands of Kenya Colony comparatively little more is done to prepare the soil, but in the East African Highlands the land is well ploughed and harrowed.

The Sisal plant rarely sets seed and its propagation is therefore effected by means of bulbils or suckers, the latter being usually preferred. The bulbils are generally grown in nursery beds until about 8 to 12 inches high and are then planted out. Planting is done in the rainy season, all fibrous roots and lower leaves having been first removed from the young plants in order to facilitate new growth. The space allowed to each plant varies a good deal in practice but perhaps the most satisfactory plan is to set the plants in rows about eight feet apart with consecutive plants about six feet from one another in the row. This arrangement gives 48 square feet to each plant and provides for about 900 plants per acre. This is the most usual spacing given in the Highlands of East Africa, but at the Coast only about 32 square feet are allowed to each plant, giving about 1,300 plants per acre. The wider spacing is possibly an advantage as it is usual to leave one sucker in the row to replace the old plant.

The period which must elapse before harvesting can be commenced varies in different countries. In East Africa the first leaves can be cut when the plants are between three and four years old, whereas in Mexico the leaves of the henequen plant are not ready for cutting until the sixth year after planting. The cutting is effected by means of a special form of blade or sickle with a curved end. The oldest leaves, that is, the lowest on the trunk, are cut first. Each is cut off close to the trunk, care being taken not to injure the younger leaves on the plant. The number of leaves

Illustration No. 4.

Sisal plants "poling."

Illustration No. 5.

Cutting Sisal leaves.

Illustration No. 6.

Cut leaves awaiting transport.

which can be cut per annum varies greatly. In Kenya about 70 leaves are removed at the first cutting whilst subsequently two cuttings of about 25 leaves each are taken annually. Each plant should thus yield about 250 to 300 leaves during its life of 7 to 8 years. In Mexico the henequen plant yields only about 25 leaves a year, but cutting can generally be continued for 10 to 15 years and occasionally longer.

The Sisal leaves produced in East Africa weigh on the average about 2 lb. each and yield about three to four per cent. of dry fibre or about 60 to 80 lb. of fibre per 1,000 leaves. In Mexico, the henequen leaves weigh less but furnish a larger yield of fibre, usually stated as between four and five per cent. This is probably due to the fact that the plant in Mexico is grown under arid conditions so that the leaves contain less water than those grown in the moister soil and climate of East Africa. It has been estimated that, on the average, 1,000 henequen leaves give about 75 lb. of fibre. When it is remembered that the Mexican fibre is not so well cleaned as the East African but contains a good deal of impurity, it is evident that the yield of fibre per leaf is not much greater in the case of henequen than in that of East African Sisal. From the figures given it will be seen that in East Africa the annual yield of fibre should amount to about one to one-and-a-half tons per acre.

The leaves, after being cut, are tied into bundles and loaded into trucks, which run on trolley-lines laid through the plantations and convey the leaves to the factory. The factory is generally placed at the lowest point on the estate in order to facilitate the transportation of the leaves ; it is desirable that it should be as centrally situated as possible and attention must also be paid to the source of the water-supply.

The factory is equipped with a fibre-extracting machine or " decorticator " and also with brushing machinery and baling presses. The principal types of decorticator now used in East Africa are those made by Robey and Company of Lincoln and the " New Corona " machine manufactured by the German firm of Krupp. In both these decorticators the leaves are crushed and the epidermal tissues and pulpy matter are scraped away from the fibre. The leaves on arrival at the factory are removed from the trucks and placed on a conveyor belt which feeds them sideways into the decorticator. They then pass over concave saddle-plates where they are stripped

Illustration No. 7. Transport of leaves to factory.

by steel or bronze knives bolted to revolving drums. During this operation jets of water are played into the decorticator which wash the fibre and help to free it from loosely adhering leaf-pulp. Abundance of water must be applied to obtain the whitest fibre. The water carries away the refuse down a drain leading to an adjacent gully.

The washed fibre is hung out in lines to dry either on ropes or on Sisal " poles " (the stalks on which the flowers are borne). The dry fibre is returned to the factory and thoroughly brushed by means of special machinery. This treatment removes any pulp still adhering to the strands of fibre, combs out the hanks and greatly improves the appearance of the product. This is one of the reasons why East African Sisal is superior to Mexican henequen, and there can be no doubt that careful attention to washing, brushing, grading, and packing neatly in press-packed bales has brought it rapidly to the front and greatly accelerated its absorption into commerce in close competition with other fibres, the cultivation and preparation of which have not been carried out on such scientific lines. The presence of impurities in fibre adds to its weight and obviously reduces its value. In the process of cordage manufacture the impurity is removed as dust and, as the purchaser has paid the price of fibre for it, he suffers a corresponding loss.

Systematic research is gradually evolving a type of machinery that ensures the production of a fibre which responds exactly to the needs of the manufacturer. This has given East Africa an advantage over those countries which once enjoyed the monopoly of this class of fibre and which are now endeavouring to follow in the same line of progress.

Illustration No. 8. Decorticating Sisal.

PRODUCTION OF SISAL HEMP IN BRITISH COUNTRIES.

The development of the Sisal growing industry in British overseas countries has taken place very rapidly during the last 20 to 30 years and has now assumed large proportions. Attempts have been made to grow the crop in the following countries :—*Africa :* Tanganyika Territory, Kenya Colony, Uganda, Nyasaland, Zanzibar, Mauritius, Nigeria, Sierra Leone, Gold Coast, Union of South Africa, South-West Africa and Rhodesia ; *Asia :* India, Ceylon, Malaya and North Borneo ; *West Indies* and the *American Continent* : Bahamas, Jamaica, Cayman Islands, Caicos Islands, Antigua, British Guiana, British Honduras; and *Australasia :* Queensland, Northern Territory, Papua, Solomon Islands and Fiji.

Reference to the trials carried out in all these countries and an indication of the possibilities in each will be found in a paper by Dr. Ernest Goulding which was published in the " Bulletin of the Imperial Institute," Vol. XXII (1924), No. 1, pages 39–55.

The particulars given in the following paragraphs are restricted to those countries which are actually producing the fibre on a commercial scale. The quantities exported from these countries during the years 1923–1927 are stated below :—

Exports of Sisal hemp, 1923-27.

From	1923	1924	1925	1926	1927
	tons	*tons*	*tons*	*tons*	*tons*
Tanganyika	12,845	18,428	18,276	25,022	30,546
Kenya	8,820	11,416	14,363	14,928	15,839
Nyasaland	747	799	785	529	801
Gold Coast	—	87	176	456	279
Ceylon	—	—	171	262	212
Bahamas	2,146	1,812	2,264	1,693	not yet available
Jamaica	237	186	239	293	do.

Mandated Territory of Tanganyika.—The introduction of the Sisal plant into East Africa was brought about in the following manner. In 1836, Dr. Henry Perrine, who was for many years United States Consul in Campeche in the Yucatan peninsula and had become well acquainted with the different agaves and their relative value for fibre production, despatched some plants (of the so-called " Yax-ci " variety) to Florida with a view to their cultivation for fibre-production; from Florida the plant made its way into the Bahamas and adjacent parts of the West Indies. Dr. Perrine's reason for selecting the " Yax-ci " agave was that he and other authorities considered it the best and most valuable of the Mexican varieties as well as being that best suited for transplanting to a moister climate. In 1892, Dr. Richard Hindorf suggested to the German East Africa Company that Sisal would be a suitable crop for cultivation in Tanganyika (then German East Africa) and, in the following year, after overcoming various obstacles and difficulties, he succeeded in obtaining a small consignment of plants from Florida. The plants which survived the journey were set out on a plantation at Kikogwe, now one of the plantations of the Amboni Estates, Limited, but comparatively few of them made satisfactory growth. Their careful cultivation and multiplication, however, have given rise to the numerous plantations which now cover enormous areas in Tanganyika and Kenya.

Illustration No. 9. Drying the fibre.

In 1899 machinery was introduced into German East Africa for extracting the fibre. By the beginning of 1900, no less than 150,000 plants had been established, of which 4,000 were more than three years old, and were ready for cutting. The first shipment of fibre was made in 1900 and amounted to $7\frac{1}{2}$ tons. From this time forward the industry progressed with remarkable speed, until in 1912 the total area planted with Sisal amounted to 61,162 acres, and in 1913, 20,835 tons were exported.

The industry was seriously affected by the war, and on the establishment of British administration in 1920 it was found that many of the best plantations had undergone serious deterioration. The situation has been gradually retrieved, and in 1926 and 1927 the exports amounted to 25,022 and 30,546 tons respectively. The area devoted to the crop in 1926 was over 114,000 acres, and it is anticipated that the production will continue to increase. Standard grades have been established, and this policy has facilitated the marketing of the crop by increasing the confidence of importers.

The Sisal produced in Tanganyika is of excellent quality, and realises the highest prices, being usually quoted at about 10 per cent. in advance of Mexican Henequen.

Kenya.—The cultivation of Sisal in British East Africa (now Kenya) was first undertaken by Messrs. Swift and Rutherford, who in 1903 planted 1,000 acres at Punda Milia near Fort Hall and subsequently erected a factory and equipped it with machinery for extracting and baling the fibre. Excellent results were secured, and the encouragement thus obtained led to a gradual extension of the industry. It was found that plants grown at the coast yielded a higher percentage of fibre than those grown in the Highlands and also furnished a finer fibre, but that in the Highlands a larger yield per acre was obtained and the cost of labour was less. In 1913 about 7,000 acres had been planted; in 1916–17 there were about 15,000 acres devoted to the crop, whilst in 1926 the area amounted to no less than 60,197 acres. Production of the fibre has increased at a similar rate; the exports increased from 1,073 tons in 1913–14 to 3,421 tons in 1916–17 and 15,839 tons in 1927.

Improvements made during recent years in the organisation and management of labour and the increase in the output of the factories have effected considerable economies in the cost of production; and these factors, in conjunction with a lowering of the transport rates,

Illustration No. 10. Brushing room.

have enabled the industry to be carried on even when the market prices of the fibre are comparatively low.

There is a considerable area of land in Kenya which is well adapted for Sisal growing, and the further expansion of the industry depends chiefly on the introduction of capital and the supply of the necessary labour.

Nyasaland.—Sisal has been found to grow well on loose sandy soils in all parts of Nyasaland, but the cultivation of experimental plots at various altitudes in the Protectorate has shown that the best results are obtainable at elevations not exceeding 2,500 ft. This area is, however, somewhat handicapped by its distance from the coast and high transport charges.

In 1926, an area of 6,312 acres was under cultivation, of which 4,625 acres were in the Lower Shire District and 1,587 acres in the Cholo District. The export of fibre in 1927 amounted to 801 tons.

Gold Coast.—An interesting experiment in Sisal growing has been carried out by the Government of the Gold Coast. During the German occupation of Togoland large plantations of Sisal were created, two of which subsequently came under British administration. These plantations proved so successful that in 1920 it was decided to plant an area of 1,000 acres on a site a few miles west of Accra, with the object of demonstrating that the dry plains at present lying waste in this region can be profitably cultivated. The plantation is intended to serve as the centre of an industry which it is hoped will be adopted by the native farmers as soon as they have appreciated the value of the crop. A central factory was erected and equipped with modern fibre-extracting machinery. The Government are under agreement with the local chiefs to hand the plantation and machinery over to them when the capital outlay has been recovered and when they have proved themselves competent to carry on the enterprise. In the year 1926–27, 2,436 acres were under cultivation, and the production of fibre amounted to 459 tons.

The local farmers are being encouraged to plant Sisal especially in the neighbourhood of the Government plantation, and advice and assistance are being freely offered to them. There are many miles of country suitable for the cultivation, and it is hoped that an extensive industry may eventually be created.

Ceylon.—Sisal was grown for several years by the Department of Agriculture of Ceylon at the Maha Iluppallama Experiment Station in the North-Central Province and satisfactory results were obtained. In 1918 this station was closed, but with a view to continuing the experiments and extending the cultivation a syndicate was formed which was granted a concession of 2,200 acres of Crown Lands on special terms. Work was started in 1919 and progress has been made.

Since 1918 the Agricultural Department has had areas of Sisal under cultivation at Anuradhapura, also in the North-Central Province, where a small mill has been established for extracting the fibre. The Department is also undertaking small experimental trials at Jaffna and Hambantota, in the extreme north and extreme south of the island respectively.

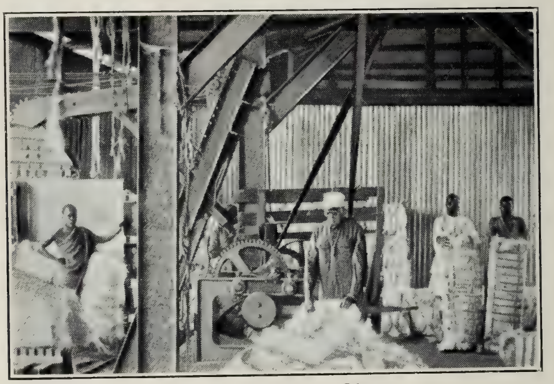


Illustration No. 11. Baling the fibre.

Bahamas.—The Sisal plant has long been acclimatised in the Bahamas, but was not seriously regarded as worthy of systematic cultivation until 1888, when the Governor of the Islands (Sir Ambrose Shea) took steps to encourage the establishment of a local fibre industry. During the next few years several large undertakings purchased extensive tracts of land and planted them with the Sisal agave. The industry developed rapidly, the maximum exports being reached in 1916, when 3,739 tons were shipped. Nearly the whole of the fibre exported from the Bahamas enters the United States on account of its favourable geographical position.

The production of Sisal has proved of much value to the Bahamas, and, owing to the resistance of the crop to drought, it has been of great financial assistance to the people at times when other crops have failed.

Jamaica.—In 1917, the Jamaica Government commenced an attempt to develop Sisal cultivation in the island. A Sisal plantation was established at Lititz on land which was regarded as useless for other crops, and a factory was erected at the northern extremity of the plantation, so that the adjacent lands, which are in private possession, might be planted with Sisal and the leaves sold to the factory on a co-operative basis.

In 1922 there were 1,141 acres devoted to the crop at Lititz. The factory, which is equipped with British machinery, commenced operations in that year and 50 tons of the fibre produced were sold at satisfactory prices. There is no doubt that the savannah lands of Lititz are capable of yielding excellent fibre. The new industry has been of great advantage to the people of this district, many of whom would otherwise have suffered severe privations during periods of drought. The cultivation is being extended to other parts of the island.

CONCLUDING REMARKS.

In the foregoing paragraphs it has been shown that in Sisal we have a first-class fibre, suitable for the manufacture of high-grade cordage of all kinds. The fibre is white and lustrous, possesses good strength and flexibility, and is well adapted for all the purposes for which cordage fibres are required. Although there has been a prejudice against the use of Sisal for marine cordage, it has now been shown, as the result of trials carried out by the Imperial Institute, that this was based on a misapprehension. Moreover, if Sisal were more liable than other fibres to be deteriorated by the action of sea-water it is unlikely that the Swedish navy would have installed Sisal ropes on their vessels or that the German fleet should have been equipped with such ropes during the Great War. Fishermen who have used the fibre for their twines and trawling-nets speak very highly of its durability and also of its power of withstanding transverse strains.

Manufacturers are therefore advised to turn their attention to East African Sisal, which they will find superior in many respects to other cordage fibres. British firms, both at home and overseas, will doubtless endeavour to increase their utilisation of the fibre for the added reason that by so doing they will assist the Sisal growing industries of British East Africa and other parts of the Empire, and thus promote inter-colonial trade and the development and well-being of the Empire as a whole. For the furtherance of such Empire trade the Empire Marketing Board was set up by the Government in 1926, and appeals to all citizens of the British Empire to give their preference, wherever possible, to Empire products.

Acknowledgements.

The Advisory Committee on Vegetable Fibres of the Imperial Institute wish to acknowledge the kindness of the following :—

Messrs. Craven & Speeding Brothers, Ltd., of Sunderland, who lent the blocks of illustrations Nos. 2, 3 and 7 ;

Messrs. Robey & Company, Ltd., of Lincoln, who lent the blocks of illustrations Nos. 5 and 6 ;

The British Central Africa Company, Ltd., for permission to reproduce illustration No. 1 ;

H.M.'s Eastern African Dependencies Trade and Information Office for permission to reproduce illustrations Nos. 4 and 11 ;

The Ruvu Estates, Ltd., for permission to reproduce illustrations Nos. 8 and 10 ; and

Messrs. Wigglesworth & Company, Ltd., for permission to reproduce illustration No. 9.

PUBLICATIONS OF THE EMPIRE MARKETING BOARD.

A certain number of copies of the following publications are available, and may be obtained, free of cost, on application to The Secretary, Empire Marketing Board, 2, Queen Anne's Gate Buildings, London, S.W.1.

Leaflets :

- The Empire Marketing Board—a brief description of the Board's work.
- The Empire Marketing Board and the Home Producer.

Booklets :

- A Calendar of the Fruits and Vegetables of Empire.
- What Milk Can Do.

Irrigation in the Empire :

- Memorandum and Questionnaire. By B. A. Keen, D.Sc., F.Inst.P.

Fruit Growing in the Empire :

- Standardisation of Horticultural Material, with special reference to Root-stocks. Memorandum and Questionnaire. By R. G. Hatton, M.A.

Fruit Growing in the Empire :

- Effect of Nutrition on Fruit Quality. Memorandum and Questionnaire. By Prof. B. T. P. Barker, M.A.

Agricultural Education in the Empire :

- Memorandum and Questionnaire on the Dissemination of Results of Scientific Research among Primary Producers.

E.M.B. 11.

VITICULTURAL RESEARCH

MEMORANDUM

By

D. AKENHEAD, M.A., B.Sc.

NOVEMBER, 1928

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses;
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller.

1928.

Price 1s. 0d. Net.

70-221-11.

PREFACE.

THIS report is designed as a companion to the report on the Chemistry of Wine Making by Professor J. T. Hewitt which was issued in March, 1928, as E.M.B. 7.

It treats of the purely viticultural aspects of wine production, and is the result of a close study of existing literature, supplemented by a tour of some of the principal European wine-producing areas undertaken in the late summer of 1927.

Some attention is given to the special question of the cultivation of the vine for table grapes and raisins. The main purpose of the report, however, is to assist those engaged in the production of wine in Empire countries by a consideration of the most effective combinations of climate, soil, stocks and methods of cultivation, as distinct from the actual technique of the wine-making processes.

WALTER ELLIOT,
Chairman of Research Grants Committee.

Empire Marketing Board,
November, 1928.

(33843) Wt. P.1322/459/850 1500 11/28 Harrow G.3

AUTHOR'S PREFACE.

THIS report does not attempt to replace in any way the manuals of viticulture at present existing. It is based on notes taken by the author during a short tour made just before the 1927 harvest, through certain of the best-equipped viticultural districts in Italy, France and Germany, and on publications in English, French, German and Italian dealing with recent viticultural research.

The author has tried to discover in the different districts the point reached by research and the most urgent problems demanding solution.

The actual building up process of modern vine growing has varied slightly from place to place according to climate, soil, human demands and human ingenuity, but the broad principles on which a healthy viticulture must be based are set out in many manuals on viticulture such as those of Babo and Mach in German; Chancrin, Pacottet and Durand in French; Cavazza, Cettolini, Molon and others in Italian, and by Hedrick and Perold in English, to quote but a very few. The last, "*A Treatise on Viticulture,*" by Dr. A. T. Perold, of Stellenbosch, published by Macmillan, appeared first in 1927, and in it the author has made full use of all recent research results.

Before proceeding with the subject matter of the report, the writer wishes to acknowledge very fully and warmly the great help afforded by Mr. J. R. Cahill, C.M.G., Commercial Counsellor to H.M. Embassy at Paris, who not only gave him invaluable personal introductions and so opened many a door otherwise tight closed, but also enabled him to cover by the use of his car and his knowledge of routes and persons a far wider field than would otherwise have been possible.

He must also thank the International Institute of Agriculture for permission to undertake the work while still remaining on the staff of that Institute, for assistance in introductions and for free access to its valuable library.

He specially thanks Mr. R. G. Hatton for his warmly appreciated assistance in the arrangement of the report.

He owes a debt of gratitude to the following gentlemen for their courtesy and help :—

Mr. Addé, Pauillac on Gironde.
Avellino : The Director of the Agricultural School, Avellino, Italy.
Mr. Bariol, Secretary of the National School of Agriculture, Montpellier.
Beaune : The Director of the Viticultural School of Beaune, Côte d'Or.
Professor Biermann, The Viticultural School of Geisenheim on Rhine.
Dr. Boselli, The Royal School of Agriculture, Portici, nr. Naples.
Mr. Charles Bouchard, Beaune, Côte d'Or.
Professor Briganti, The Royal School of Agriculture, Portici, nr. Naples.
Mr. R. Brunet, Editor of the Moniteur Vinicole, Paris.
Mr. A. Cadoret, Chambery, France.
Dr. F. Carpentieri, Ministry of National Economy, Rome.
Conegliano : The Director of the Royal School of Viticulture, Conegliano.
Mr. D. Cordier, Château Lafaurie-Peyraguez, nr. Bordeaux.
Messrs. Denman, Château Livran, nr. Bordeaux.

Dr. R. Dotti, Lugo, Romagna, Italy.
Mr. Durpretis, Frascati, nr. Rome.
Ecully: The Director of the Agricultural School of Ecully, nr. Lyons.
Dr. H. Faes, Federal Research Station, Lausanne.
Professor Ferré, Oenological Institute, Beaune, Côte d'Or.
Dr. Gante, The Viticultural School of Geisenheim on Rhine.
Mr. Gibert, Château Haut Brion, nr. Bordeaux.
Messrs. W. & A. Gilbey, Château Loudenne, nr. Bordeaux.
Mr. Lafforge, Director of the Office Agricole of the Department of the Gironde, Bordeaux.
Mr. Laprugne, Director of the Office Agricole of the Department of the Vaucluse, Avignon.
Mr. Latour, Aloxe-Corton, nr. Beaune, Côte d'Or.
Professor A. Manaresi, The Royal School of Agriculture, Bologna.
Mr. Marsais, The National Institute of Agriculture, Paris.
Mr. E. Moreau, Epernay.
Mr. Mortier, Bordeaux.
Oberlin, Viticultural Institute, Colmar.
Mr. G. H. Olliver, Rheims.
Dr. Paillôt, St. Denis Laval, Rhône.
Mr. Piguet, Federal Research Station, Lausanne.
Dr. Prosperi, Viticultural Research Station, Velletri, nr. Rome.
Professor Ravaz, National School of Agriculture, Montpellier.
Baron Ricasoli, Casa Vinicola Brolio Chianti Ricasoli, Florence.
Messrs. Richter, Montpellier.
The Barons Edmond, Edouard and Robert Rothschild, Château Mouton Rothschild, nr. Bordeaux.
Baron H. de Rothschild, Château Lafite, nr. Bordeaux.
Mr. Salomon, Thomery, Seine et Marne.
Mr. de Sur Salmes, Château Yquem, nr. Bordeaux.
Mr. Toinon, President of the Chamber of Commerce, Villefranche, Rhône.
Messrs. Vermorel, Villefranche, Rhône.
Messrs. Veuve Clicquot-Ponsardin, Rheims.
Professor Zschokke, The Viticultural School of Neustadt on Haardt.

CONTENTS.

VITICULTURAL RESEARCH.

I. VITICULTURE IN EUROPE.

BEING an account of a tour made between September 10th and October 10th, 1927, together with notes on the chief viticultural stations.

Vineyards.

Chianti.—The vineyards visited here under the guidance of Dr. Mario Topi of phylloxera fame were those of the Barone Ricasoli at Brolio, near Siena in Italy.

The vines are grown on the mixed cultivation system, i.e. in rows about 4 yards apart, 1 yard between vines, with an olive tree planted every 4 or 5 yards in each row. The land in between the rows is normally under a three-course rotation of maize, legumes, wheat. The preparation of the land is arduous, the actual friable soil being very thin, while the compact Eocene rock beneath, which after a few years weathers to an excellent vine soil, is extremely hard to move initially.

Phylloxera has slowly done its work and any new vines planted are usually grafted on the spot, this system allowing, in the case of one graft failing in the spring, another to be tried in early summer.

Among vines recently grafted, considerable divergency in growth and in vigour exists among the same varieties of scions grafted on the same stocks. This, however, was said to be temporary, and certainly in the three or four year grafted vines these differences were not seen.

In those parts directly cultivated by the firm itself, specialised culture is taking the place of the mixed culture as described above, but most of the land is cultivated on the Métayer system, where the métayer prefers not to have all his eggs in one basket and so spaces his vines and practises interculture. Such interculture explains the slow spread of phylloxera in the district, but it adds to the work of spraying and other cultivation operations, and in a district of greater moisture would be therefore a great disadvantage.

The scions used for Chianti are red Sangiovese, black Caniolo nero, white Trebbiano and Malvasia.

The vine crop in 1927 showed promise of good quality but not great quantity. This promise was later fulfilled.

Romagna.—At Lugo, in Romagna,[30] were seen the typical "alberati" vines, i.e. vines trained on trees. The practice here is to grow the vines in rows 20 to 30 yards apart, supported on trees, distant about 6 yards from one another, the vines being planted in the gaps between and trained along to the tree. The most suitable tree is the maple, the *Acer Campestris*, as its root system is small and does not compete with those of the vines, it forms a strong support with a thick protective foliage and, in addition, it stands very well the periodical and necessary cutting back which it receives. These qualities are not so pronounced in the other types of tree used, i.e. elms and poplars.

Such a practice is probably not one to be recommended for the establishment of vineyards in a new vine growing area, but it must be admitted that the protection offered by the leaves of the protector plant against hail, the effects of which were very obvious in other parts of the district where no such protection existed, was very noticeable.

(33843) B

There had been no serious trouble with any type of disease in 1927. Great stress was laid on keeping the vines well aerated. Types cultivated are Trebbiano—Uva d'Oro—Canina—Cagnina.

Bordeaux.—At Bordeaux, the vineyards of the following châteaux were visited: In the Médoc district, Margaux, Mouton Rothschild, Loudenne, Livran, Lafite; in the Graves, Haut Brion, and in the Sauterne, Yquem, La Tour Blanche and Lafaurie-Peyraguez.

A feature was the uniformity of growth of the vines and the lack of gaps among them. Such gaps as do appear are generally due to apoplexy.

In a few of the vineyards there still linger old ungrafted native vines. M. Addé, British Consul at Pauillac on the Gironde, has some of over 100 years old which still crop well: but wherever new planting has to be done, there is never the slightest suggestion that anything but grafted vines shall be planted.

The visit was made in rainy weather about ten days before the harvest was due to start.

The most striking contrast was the change from mixed to single culture, and from tree to wire support. In Northern Italy the vine, though of possibly paramount importance, is only one of several crops. In Bordeaux it is, generally speaking, the only crop, on the success of which everything depends.

Hence, as might be expected, healthier and on the whole more formidable looking vineyards were seen. The later rains had been somewhat disastrous and had induced the formation of a great deal of grey rot (*Botrytis cinerea*). This was much more noticeable in Médoc than in Graves or Sauterne, and it may be noted in this connection that, whereas the common distance between vines in the rows in Médoc is about 1·20 metres and between rows only 80 cm., which does not facilitate spraying and cultural operations, the vines moreover being trained very low with some bunches touching the ground, those in the Graves and Sauterne districts have at least 1 metre between the rows and are trained higher, so that far more air circulates around them, and spraying and cultural operations are thereby facilitated.

Damage by other disease was not generally visible, though uneasiness is expressed regarding the possible spread of Eudemis and Cochylis (*Polychrosis botrana* and *Clysia ambiguella*), especially the former.

The growers visited in no case did their own grafting, but all resorted to firms of excellent repute either in the district or farther south, in the Midi, a region of famous nurseries, where soil and climate produce such young vines as the North cannot do.

At Haut Brion 95 per cent. of the grafted vines planted are said to be successful.

Hybridisation does not at present interest the growers of the famous "crus" of Bordeaux. To preserve the character of their wine they must keep to the old varieties which have existed there for centuries. Such are Cabernet Sauvignon, Gros Cabernet, Merlot, and Malbec for the red, and Sémillon and Sauvignon for the white wines.

The Côte d'Or or Burgundy springs at once to the mind as a region for comparison with that of Bordeaux. Both wines are equally famous, and although it is rare to find a Burgundy with that exquisite delicacy of bouquet and flavour which can be appreciated in a fine Médoc, yet a Burgundy is perhaps naturally more suited to the English taste as more certain to expel from the system the cold wet vapours of an English winter.

Burgundy.—In Burgundy it is to the wine merchant one must go for information on vines, rather than to the actual grower, and although here and there one sees the name of

some Château, it does not usually connote, as in the Médoc, an entirely self-contained unit, doing its own bottling and having capacious cellars for storing the wine of many years.

One large estate, however, was visited—that of M. Latour at Aloxe Corton—and here were to be seen wine growing practices which serve as a model to the district.

The varieties of French scions used are the Pinot Noirs for the red wines of quality, the Gamay for the vins ordinaires, Melon in the plain for the local wine.

All plants are bench grafted, the chief rootstocks varying according to the lime content of the soil.

Very few gaps were seen. A certain amount of grey rot was visible, but the general condition of the vines appeared better than in Bordeaux. The vintage was actually finished in splendid weather and the quantity of wine was more than in 1926 though below the average.

Beaujolais.—Beaujolais nowadays is, as it were, a less renowned Burgundy, its wine, with a few exceptions, not being able to compare in keeping qualities or body with that of Burgundy. The red is based mainly on numerous types of Gamay, e.g. G. Picard, G. Nicolas, G. de Veaux or Geoffray, whilst the white is chiefly made from Chardonnay, a variety of White Pinot.

At Villefranche sur Saône, the heart of the Beaujolais country, an interesting sidelight was thrown on viticultural practice as affecting vinification. The vin ordinaire was found appreciably more palatable and excellent than five- or six-year bottled wine of a well known firm of excellent repute. The opinions of two experts consulted later differed somewhat. One declared that new Beaujolais is remarkably good because fermentation is not carried to excess, and the full flavour of the fruit always remains in the new wine, a flavour which is lost later in favour of added softness; whereas the second said that Beaujolais is apt to upset the stomach owing to the grapes being harvested when unripe.

Alsace.—The Alsatian vineyards are, as might be expected, more closely allied in practice with those of the Palatinate and the Rhine than with any others.

The centre of their activity is Colmar, where is the Oberlin Viticultural Establishment ready and capable of giving sound advice.

Germany.—Attention is now concentrated on the production of a white wine of quality with a very distinguished bouquet, which will attain perfection in a few years, 5–6, about which age it should usually be drunk.

The wine grapes most favoured are according to Meiszner[51], (1) for white wines: Weisse Riesling of different varieties, Grüne Sylvaner, Weisse Elbling, Weisse Gutedel, Gelbe Muskateller, Weisse Burgunder, Rote Traminer, Graue Rülander, Rote Velkeliner; (2) for red wines: Blaue Portugieser, Blaue Burgunder, Müllerrebe, Trollinger, Limberger, Affentaler.

The closest attention is now being paid in Germany to effective control measures against the Cochylis and Eudemis moths ("Heu—und Sauerwurm"), which have done untold damage in the last few years, especially in 1925.

Champagne.—In Champagne, the cellars, the grafting house and experimental vineyard of Moët and Chandon, as well as some of the vineyards of Veuve Clicquot-Ponsardin were seen. A notable difference was visible near Epernay between the modern well-kept vines of the wealthy firms and adjacent vines, planted in accordance with old tradition, purposely at random, so doubling the cost of efficient cultivation. The two chief varieties are Pinot noir and Chardonnay blanc.

Seine et Marne.—The nurseries of M. Salomon of Thoméry, the centre of the thriving table grape industry were visited, further mention being made in Chapter V of the preservation processes adopted there.

Hérault.—Hérault in viticulture is famous for three reasons, namely: the highest production of wine of any province in France; the renowned Viticultural School at Montpellier; its viticultural nurseries, (*see* page 19.)

Viticulture in Hérault is the very life of the countryside. Luxury wines find no place here, but good wholesome wine is produced on an enormous scale throughout the province and despatched to every corner of France. Moreover, both for the purpose of rearing young stock and for quantity of produce Hérault is unsurpassed. Here is found nearly every type of soil, from the sand of the Camargue, home of innumerable flying, biting insects, and of the mistral* and its intolerable salt—which must first be eliminated by irrigation and rice-growing—to the big quartz pebble soils near Aigues Mortes, where boulders the size of one's fist are the rule, where Aramon grows in great, heavy bunches and wine is not lacking.

It is a district where in such soils, as are little subject to phylloxera, direct producers (*see* page 14) are much used.

The properties are either fairly large, some 20 acres or so, and are managed by agents, or are small family concerns of some 3 or 4 acres, only the product of the vine in both cases being marketable.

The smaller man is normally a member of a large co-operative wine factory, such as that of Marsillargnes, which is capable of dealing with 1·2 million hectolitres of wine. On a record day of 1927 nearly 90 tons of grapes were accepted and dealt with.

The plain is largely planted with Aramon at the rate of 3,600 vines per hectare.

The pebbly ground of St. Gilles du Gard in Grès grows unstaked Aramon producing in parts 100–120 hl. a hectare, or rather less.

In the plain of the Vistre, submersion of the vine is practised (*see* page 14). Diseases are not very serious and appear to be considered rather in the nature of "murrains" or acts of God without further differentiation, though the effects of mildew, cochylis, white rot, &c., can be seen.

The French vine grower, like agriculturists the world over, is extremely conservative, but there are two factors which make and keep him progressive :—(1) Vine-growing is in his blood : it is vines, or nothing, and although the use of American rootstocks may halve the life of the plant, a man does not willingly sacrifice a planted vineyard likely to last even a mere 20 or 30 years ; therefore he reconstructs rather than abandons. (2) Diseases come thick and fast—oidium and mildew, phylloxera, and now eudemis and cochylis. The French grower watches them all, and, while mistrusting cranks, is very much alive to the practical results of modern research.

Viticultural Stations.

Montpellier.—The National School at Montpellier in Southern France is the most famous of European stations. Students come there from all parts of the world where grapes are grown, and it is enough to mention the work done there by such men as Ravaz, Viala, Verge, to show the supreme importance of this establishment.

The grounds contain the largest known collection of vines, and constant opportunity is to hand for observing every type of practical experiment whether on grafting, spraying, manuring or other practice.

---

* A violent, cold north-west wind.

Ecully.—Here within a few miles of Lyons and close to the entomological station of the south-east of France is a thriving horticultural station, with an up-to-date viticultural side. Teaching and experimental work go hand in hand, special emphasis being laid on the practical side. The writer was impressed by the number and well-kept appearance of the different types of vine.

Beaune.—Beaune possesses both a small viticultural school, where work is carried on for the benefit of the viticulturists of Burgundy, and an ably directed oenological station with a somewhat wider compass.

Colmar.—The Oberlin station, so named from its famous founder, lies just outside Colmar and has great influence on Alsatian viticulture.

Work is at present concentrated on accelerating the change from vineyards producing quantity to those specially giving quality. This process cannot be a fast one and it can only succeed after many years patient work in the adaptation of new and more carefully selected varieties and in certain alterations of the pruning and cultivation systems.

Villefranche sur Saône.—Beaujolais is fortunate in possessing an absolutely first-rate private viticultural station at Villefranche. This was founded and directed by M. Vermorel, the maker of the well-known spraying apparatus which bear his name. Free information on viticultural and horticultural subjects is given on demand. It is furnished with the most modern laboratories, a very valuable collection of plants and diseases and a thoroughly up-to-date library of more than 25,000 selected volumes on viticulture and horticulture.

A few weeks after his visit the writer heard with the utmost regret of the death of M. Vermorel.

Geisenheim and Neustadt.—In Germany viticultural practice is intimately connected with the two important viticultural schools and research stations at Geisenheim on the Rhine and Neustadt on the Haardt.

These are eminently practical schools, aiming at giving practical benefit to students who come for short or long courses, and by publications and otherwise at keeping German viticulturists well advised as to the best methods of establishing and preserving intact healthy, paying vineyards.

Lausanne.—The writer's visit to the station at Lausanne was unfortunately very brief and it was impossible to make any tour of the experimental grounds.

The laboratories, however, for oenological and viticultural purposes were equipped on a scale not seen elsewhere, while the quality and quantity of work accomplished by Dr. Faes and his assistants, which is referred to later in this report, is a remarkable contribution to progress in viticulture.

Wädenswil.—This station acts more or less in the same capacity for German speaking Switzerland as does Lausanne for the French speaking part. Both are now Federal Institutions. The former was founded in 1886, the latter in 1890.

The chief Italian stations are :—

Conegliano.—Conegliano, lying north of Venice in the old Piave war area. Here experiments on hybridisation and on direct producers have been undertaken since the end of the war and are now in progress.

Alba.—Alba, near Turin. The work at both of these stations would appear to concentrate on the problems facing viticulturists of those particular districts of northern Italy.

Avellino.—Avellino some 50 or 60 miles south-east of Naples performs the same function for southern Italy. It holds two long courses of four years and three years.

Palermo.—At Palermo, in Sicily, are the great Government vine nurseries, where a considerable amount of rootstock investigation takes place.

Catania.—There is a further government station at Catania.

Velletri.—The chief table grape experimental station in Italy is at Velletri, 25 miles from Rome. First under Longo and now under Prosperi it has done and is doing work of supreme importance. The station possesses some 34½ acres and has a collection of 850 varieties of vines of which some 300 are table varieties.

The chief aims of the station are :—(1) Training experts in grafting, training and vinification and giving advice on these subjects. (2) The distribution of rootstocks, scions and grafted plants. (3) The distribution of the best variety of vines tested for the district. (4) The creation of new varieties and the testing of adaptability of different rootstocks and scions.

II. PROPAGATION.

The viticulturist of to-day asks two questions :—Need I graft ? If I graft, what rootstocks am I to use ?

Necessity for Grafting.—As regards the first, despite the outcry raised by Daniel and others against the whole system of grafting, it is now generally accepted by the competent authorities in the wine growing countries of the world that, wherever there is a chance of the coming of phylloxera during the lifetime of the vines about to be planted, only vines grafted on phylloxera resistant stocks should be planted. Submersion as practised in one or two places near Bordeaux and elsewhere is not usually possible, while treatment with carbon disulphide if applied in sufficient strength to destroy phylloxera destroys the vines as well. Direct producers have not as yet been found combining resistance to phylloxera and to fungi with a capacity for yielding sufficient grapes whence a fine wine can be produced.

Direct Producers

A direct producer actually signifies a vine growing on its own roots, originally all vines being so grown. When, however, vines from America were introduced into European vineyards owing to the greater resistance shown by them to Oidium (*see also* page 63), it was found that an even worse scourge had so been imported. Phylloxera (*see also* page 54), which had previously been a harmless enough insect somewhat spoiling the appearance of the leaves of certain varieties of vine in America under certain conditions, was found to attack the roots of European varieties with the disastrous results now known to all viticulturists.

Nowadays the term direct producer, as defined by Durand,[31] may be considered as comprising all varieties which possess a certain resistance to phylloxera and may so be grown for the production of wine on their own roots. The original varieties which earned this title were American varieties, of which Noah, Clinton and Othello are still grown to a limited extent in the Camargue, Northern Italy[19] and elsewhere.[78]

The above are the survivors of very many similar varieties which were originally acclaimed as an alternative to grafting in France, at a time when the demand for grafted stock far outstripped the supply. Their resistance, however, to phylloxera was found to be only relative, while the wine produced by them was not generally comparable with that produced by the old varieties.

The value of hybridisation has, however, been realised, and attempts have been continuous to turn to account the innumerable varieties whose particular characteristics appear somewhat mosaic-wise in the hybrid. Thus geneticists now are seeking to localise in the leaves of direct producers the quality of resistance to mildew and to oidium, and in the roots that of resistance to phylloxera possessed by the American vines, while in the fruits the aim is the fixation of the essential vinifera characteristics, the size of berry and the freshness of taste. Contrariwise an attempt is made to eliminate the inconvenient characteristics of both parents. (*See* page 48.)

Perold dismisses the subject in a few pages, the necessity for resistance to fungi not arising in the dry air of the Cape. For the same reason not much attention is paid to them in the South of Italy.

The number of new direct producers is legion, and many have been found showing at least considerable resistance to cryptogamic diseases ; but the period of testing is long, and direct producers acclaimed in one place will be roundly denounced in another, e.g. those resistant to mildew[61] in 1910 fell victims to it in 1914 and 1915. The first extravagant hopes have now somewhat subsided under the sobering influence of lengthy trials.

The year 1927 was exceptionally favourable for testing the disease resistance of direct producers. Chauvigné,[23] in his account of observations on a very large number of direct producers in the Inde et Loire Department of France, shows that satisfactory progress has been made.

In the particular regions observed by him in 1927, the best red hybrids from the point of view of wine produced and resistance to disease were :—Baco I (23–24), Couderc 4401, Bertille Seyve 893, Bertille Seyve 872, Jurie 580, Castel 19.637, Gaillard 2. The best white hybrids were :—Baco 22A, Castel 1832, Malègue 1647–8, Seibel 4986, Seibel 4995 and 2653.

He notes that all the direct producers observed were very little attacked by the various caterpillars which feed on the vine, and that, generally speaking, they are very resistant to fungoid attack, while even those attacked can be afforded adequate protection by three sprayings.

But finally he notes that the combination of resistance to disease and the production of a good wine is still very rare.

This article aroused comment, especially from J. F. Ravat,[69] who does not agree with the merits of the hybrids placed high in Chauvigné's list. Baco I, for example, in Ravat's opinion gives a return so small as to make it useless for the ordinary vine grower. In short, he prefers other direct producers than those recommended above.

Rives,[76] in his articles on direct producers in the province of Aude during 1927, notes certain of the above list, namely Seibel 2653 as being resistant to drought, Seibel 4986 and 4995 as needing deep soils and high temperatures respectively.

Some of the direct producers in his department were found to be very sensitive to Anthracnose, e.g., Castel 19.637, Malègue 829–6, Seibel 5813, Seibel 1000 and 5163, and to a lesser degree 4995. He notes the drought resistance observed by Vivet in Algeria on many direct producers, including Baco I and Seibel 4986, and considers that those so classed would be admirably suitable for growing in the Midi.

Lausanne experiments.—The most exhaustive experiments have been in progress for many years at Lausanne[36] and some account of these experiments may give some little idea of the labour and care involved.

An attempt is made at Lausanne to produce direct producers showing the following characteristics : (1) Marked resistance to mildew. Hence the vines under experiment receive no spraying, elimination of those not showing considerable resistance being therefore easy. (2) Resistance to oidium. The problem here is much more difficult, the resistance apparently varying from year to year. Sulphur, moreover, is found to have a very destructive effect on the leaves of certain direct producers.

It should be noted that, before pronouncing on the resistance of a direct producer to phylloxera, the latter must be tried out under different conditions of soil and climate. The station of Lausanne will, as phylloxera advances, be better able to gauge this.

Direct producers which do not pass certain tests of quality of product are also eliminated. In this case, the grapes are compared at vintage time with the varieties of Chasselas and Pinot grown locally. Elimination is made for incomplete or unequal ripening, possession of any curiousness of taste such as foxiness, acidity or bad after-taste.

All direct producers are eliminated whose musts do not yield on analysis at least 14 per cent. of sugar or whose total acidity (tartaric) exceeds 15·0 gm. per litre. Finally the wine is tested.

In summarising their reports, Dr. Faes and his collaborators make among others the following statements :—

> Out of 270 varieties tried in our experimental fields 140 have been rejected as useless. We have 24 interesting direct producers, 17 with black and 7 with white grapes, the remainder being still *sub judice.*
>
> No direct producer as yet is qualified to replace our local varieties.
>
> Results justify the continuation of our research in this field.
>
> As a result of our work to date, legal permission has been given to Vaudois viticulturists to plant four of the Seibel hybrids forming part of our experimental plants, namely 156, 782, 1000 and 2738. These give a good coloured wine of common type suitable for family use.
>
> At the exhibition held by the Société des Agriculteurs et la Société des Viticulteurs de France, many direct producer wines were tested and the opinion given that some of them might be regarded as good common wines, that certain were even worth retaining as providing very good common wine, but that the wines were essentially different from those of vinifera varieties to which one was accustomed. Hence, commercially speaking, their general use could only be for mixing or in coupage in small amounts. On the other hand, they should prove useful for family use.
>
> We would also stress the fact that judges often declare that a wine of a direct producer is of value when the direct producer itself has no agricultural value. It must be remembered that a direct producer must not only produce a pleasant wine, but it should also be reasonably resistant to disease without preventive treatment and produce a sufficient weight of grapes.

The efforts of vine geneticists are now, in short, directed towards the production of hybrids which, under given environmental and climatic conditions—such varying from extreme humidity, giving full play to insect and fungus pests, to drought conditions—can be depended upon to yield an adequate crop from which a good wine may be produced.

The original aim of resistance to phylloxera is now somewhat inclined to sink into the background, as grafting becomes more and more the universal habit, and the resistance to phylloxera of many of the most popular so-called direct producers of the present day is very small.

Before it is decided to plant direct producers, trial should be made of varieties found to give good results in districts enjoying somewhat similar conditions, but it must be realised that the success of these under new conditions is by no means certain.

It will be noted, then, that although considerable progress has been made in breeding direct producers resistant to particular factors of environment and under such conditions yielding a good wholesome wine, a direct producer which will combine, again under a given set of environmental and meteorological conditions, the qualities of juice inherent in, say, a Cabernet grown under optimum conditions with resistance to insect and fungus pests is still to be found.

Grafting.

When France was confronted by the necessity for immediate action against the all destroying phylloxera, she could not avail herself of this later research and very wisely determined to reconstruct by means of grafting.

But having determined on this course, namely the grafting of the old varieties on American varieties known to be resistant to the root form of phylloxera, even vine growers of experience allowed themselves momentarily to lose their native shrewdness in joy at this long looked for saviour of their fortunes. Some of the original successful American rootstocks had only been tried on certain types of soil and under certain conditions of climate, in which their success had been proved. It was not widely understood that the American vine was much more susceptible to differences in climate and soil than the ordinary vinifera variety, and in consequence results were often thoroughly unsatisfactory.

Professor Daniel, who had realised perhaps better than others the limitation of the American vine, and who considered that the only safety lay in ruthlessness, denounced the whole practice of grafting in the strongest terms and advocated a return to the old system of soil disinfection and the growing of vines on their own roots, prophesying complete disaster otherwise.

In Daniel's famous article printed in *The Times* of 25th April, 1908, the essential points against which he inveighed were the descent of the vine from the proper vinelands to the plain, the system of long pruning, intensive culture, the sacrifice of quality to quantity, the greater susceptibility to disease, the loss of character of world famous wines, and the cessation of wine drinking owing to the adulterants now added to wines to give them an acceptable flavour.

A very full reply was made to his charges by Viala and others in *L'Ampelographie*, Vol. I, p. 717; in the *Revue de Viticulture* of 21st December, 1911, and other numbers; in *Notes et Recherches sur l'influence du greffage*[86] by Viala et Pacottet, and elsewhere.

To give even an abstract of this long and acrimonious warfare would be wearisome, but it may well be pointed out that the first three objections quoted above have nothing to do with grafting in itself, that the loss of character of the famous wines of France would seem to be a pure misjudgment of the facts of the case, that the sensibility to disease is not proven except under certain conditions which will be discussed in the next chapter, and that wine drinking has not shown any appreciable decline in France since the introduction of grafting on American stocks, either owing to the presence of adulterants or on any other account.

Nevertheless, although it is true that grafting was often originally done with more haste than wit, and that the luckless viticulturist was prone to lay the blame on the whole practice of grafting, instead of on his own lack of experience, the fact remains that the path of the early grafter was by no means smooth in those days, nor has it yet become so.

A common fault urged against grafted vines is that their life is shorter, and in many cases it has been found that grafted plants show signs of old age when 25 to 30 years old and that shortly afterwards they entirely cease to yield. Oberlin[59]* (quoting Couderc) in his plea for the reconstruction of vineyards without grafting by means of a more rational and natural system of growing the vine, which would not, however, appear to be always practicable, refers to the dire straits to which certain of the Burgundian viticulturists had been reduced, thanks to grafting. Couderc stated in 1911, that the life of a grafted vine in the Saône et Loire district was at that time only 12 to 18 years, and yet, despite this, in the same district to-day vine growers have come to the conclusion that their only salvation lies in grafted vines ; that these vines, in all ordinary cases, have a life at least double that stated above and that the famous wines of those parts suffer not a whit.

Length of life of the grafted vines depends then on all the factors which ordinarily affect the ungrafted vines and, in addition, on the affinity between scion and rootstock, and between rootstock and soil.

In the Agro-Romano, near Rome, there are still flourishing vines grafted on American stock 50 years ago. Before the invasion of phylloxera, very many centuries' experience and work had gone to the building up of the vinifera varieties which gave, under certain conditions of soil and climate, the most famous wines of Europe. It is then scarcely reasonable to expect that within the first hundred years from the date of grafting the first vine on American stock in Europe, all problems of longevity, or affinity should be solved.

It is extremely difficult to hold the scales fairly between the small, very emphatic school led by Daniel, and the more classic school whose protagonists are men such as Ravaz, Viala and others, who have given their whole life to the most careful study of viticulture and have done incalculable service in that field. It is impossible for the grafters to prove a universal negative. On the other hand, Daniel would appear to draw general and sometimes erroneous conclusions from particular instances.

In default of new scientific discovery, and despite the fact that grafting has been proved a much more intricate business than it originally seemed to be, it is on grafting that the viticulture of the future will be based.

Reconstruction in Europe.

Granted then that this fact must be faced, the general methods employed in Europe are worth noting.

It would seem superfluous to stress the necessity for absolute purity of strain in varieties both of scions and rootstocks, were it not for the fact that viticulturists in all countries have in the past continually been deceived owing to their own ignorance or to fraud on the vendor's part. The result has generally been disastrous and the viticulturist is inclined to blame rootstocks or scions which he wrongly thinks to have planted.

Germany.

Germany possesses a cold climate which affects the reconstruction of vineyards in two ways :—In the first place, owing to unfavourable atmospheric conditions the progress of phylloxera is slow, a fact which allows success to be achieved in many cases by systematic carbon disulphide disinfection, which is actually practised. At the same time reconstruction is being undertaken on American stock and advice obtained from experts in the South of France.

---

* *N.B.*—It would seem that at this period Oberlin had seen the almost naturally growing vines of northern Italy, which were not attacked by phylloxera merely because phylloxera had not yet reached those parts. On the arrival of phylloxera these vines fell victims.

In the second place the cold means considerable difficulty in the provision of sufficient American wood, as, although there are plantations of American mother vines in the Rhineland, it is extremely hard to get proper maturity of wood owing to early autumn frosts. These plantations would appear to be of more use in demonstrating the interest taken in the matter by public bodies than as an economic proposition.

At the present time large quantities of American wood are imported yearly from the South of France. It is found that the cost is less and the wood of higher quality.

France.

In France, some of the great wine firms in Champagne and elsewhere have organisations so large as to enable them to obtain all their necessary stock from their own nurseries, some in the Midi, some on the spot. Very many more obtain their stocks yearly from a nurseryman of repute, in many cases providing their own scion cuttings. The writer in visiting the vineyards of Aloxe-Corton in Burgundy was shown certain vines, which having been noted as consistently good and healthy producers for a matter of five or six years were now marked down as vines from which cuttings would now be taken for sending to the grafter employed.* The latter performs the necessary grafting operations, and after rooting in the nursery, sends them back for planting out in the field.

Very many viticulturists rely on well established nurserymen for the supply of everything. The writer was able to visit one of the best known nurseries in France, namely, Messrs. Richter's establishment at Montpellier. This firm has nurseries in the Midi and in Algiers and supplies stock all over the world, its chief products consisting of grafted plants, rooted American cuttings and unrooted grafts. The nurseries are yearly subjected to examination by the French phytopathological authorities, and, in addition, the most exacting care is paid to purity of strain. The nurseries are subjected to expert examination during the growing season and in the autumn, all those grafts or rooted cuttings which are not absolutely true to type being eliminated or in case of any doubt, marked for future examination.

The writer visiting the nurseries in late autumn, when often the colour of leaves may point to the presence of an impurity, found three single individuals which appeared untrue among many thousands of plants. On examination all three were found to have been already marked as doubtful on previous examination by means of cotton. These would therefore later be eliminated.

It is, then, possible to obtain stock of guaranteed strain or strains which has been proved to produce vigorously and well under certain conditions of soil, climate, &c. All authorities are, however, becoming more and more persuaded that no combination of rootstock and scion can be lightly regarded as bound to succeed under different environmental conditions. Thus, rootstocks successful in Northern France have not always been found to do so well in the South or in Italy[65, 58]. This fact means that, although the original grafted stock imported may be excellent, its value may change very much after a few years in a new habitat. The change may be due to climate, to different methods of cultural practice, to different sources of insect or other dangers.

Switzerland.

Faes, whose tireless researches at Lausanne are gradually establishing Vaudois viticulture on a sound basis, considers that 20 years continued experiment will probably yield results which can be relied on for choosing stock. Blunno[5] in his monograph on phylloxera-resistant stock scouts the idea, apparently current at one time in New South

* See, however, Bioletti's experiments at end of this chapter.

Wales, that 11 years should be sufficient in which to acquire certainty as to the best varieties to be grown in a given locality, and all modern experts are entirely in agreement with him.

Italy.

In Italy[37], despite energetic state intervention, phylloxera is now officially recognised as present in 74 out of 76 provinces, Aquila and Naples being the exceptions, and in June, 1927, in 5,667 out of 9,000 (odd) communes. Reconstruction has taken place and is still taking place in every district. In Sicily, Calabria and Sardinia it is nearly complete, while Apulia is very little behind. Tuscany and Venice have very large areas reconstructed. In other parts the incidence of phylloxera has not been so marked and hence reconstruction is not so advanced. But, as the writer has had occasion to note, in the vineyards of Frascati near Rome, where the nearest and isolated patch of phylloxera was still some 15 miles away in January 1928, viticulturists in planting up their land are given every encouragement to plant tested grafted stock obtainable through their local " consorzio," or association of vinegrowers, one of whose functions is to provide the grower, as far as possible, with guaranteed stock.

The government schools, such as Conegliano, Avellino, or experimental stations such as Velletri are generally in a position to supply a very limited supply of rooted grafts and rather more cuttings of guaranteed American rootstocks, rooted or unrooted, on which the cultivator himself can graft his own scions.

That all has not been plain sailing was shown by Leonardi's publication in 1927[44], wherein an account of the present position is given and certain remedies suggested. The details which follow are taken from that work.

The reconstruction of vineyards in Italy has been in progress for the last 50 years. At the beginning of the present century, the demand for American wood was on the increase and the Government was doing all that seemed necessary to meet it by the establishment of American vine nurseries in different parts of the country. At the same time, every encouragement was given to co-operation, which arose and flourished in the north without difficulty, while in the south anti-phylloxera " consorzî " or associations were established by the State in Apulia in 1901 and in Teramano in 1902. In other places too, the formation of consorzî was made compulsory. These associations gradually took over the work of the Royal nurseries as regards American wood.

In this fashion, all went comparatively well, subject to the inevitable setbacks due to lack of experience of the new vines and new conditions, until the war. During the war the tendency was to let things slide, but on the restoration of peace the demand for American stock became much more insistent and temporarily quite incapable of fulfilment. From a dishonest business standpoint the opportunity was golden and ample advantage was taken of it. The viticulturist in his haste to plant up new or phylloxera ravaged areas had recourse to anything and everything which bore the name of American stock, irrespective of whether it was a direct producer forced into doing improper work as a rootstock or a variety which had previously been found unsuitable. " American wood " dealers increased rapidly in numbers and wealth, selling their goods sometimes by weight, occasionally by number, but rarely by measure. The viticulturist, being in great haste and without sufficient knowledge of the new vines, fared terribly. Many a bundle of " first class American wood " in passing from hand to hand changed its variety as many times, now being 420A, now 3309, now 41B, according to local preference.

Appalling results were soon seen in the vineyards, and consequently Law No. 1363 of 26th September, 1920, was passed in the attempt to remedy matters. This law made it

compulsory for producers and for dealers in cuttings, rooted cuttings and grafted cuttings of American wood, to notify the Ministry, in the case of the producers (*a*) as to the areas devoted to mother plantations and to rooted cuttings, distinguishing those grafted from those ungrafted ; (*b*) as to the numbers and ages of the mother plants, numbers of cuttings planted, grafted and ungrafted, specifying the variety of both stock and scion ; and in the case of dealers, as to the numbers of cuttings, rooted cuttings and rooted grafted cuttings, and place of origin of the goods which they intended to sell.

Provisions were made for a compulsory certificate to be given at the time of sale, for inspection by the Ministry's officials at the time of grafting, for the taking and testing of samples by and for the buyer, for his reimbursement when goods were found untrue to sample, for fines of 200–5,000 liras (approx. at present rate of exchange £2–£25), for the freedom of the consorzî from the above regulations, and for the possibility of consorzî and viticultural associations acting as civil parties in the law courts.

71 Institutes were appointed to receive notifications.
44 Institutes were appointed for testing samples.

All things considered, the most hopeful safeguard here lay in the paragraph relating to the taking of samples and the naming of Institutes where such samples might be tried out. Actually, human nature being what it is, and the law certainly needing amendment as to the time and method of taking such samples, this paragraph remained, generally, a dead letter.

In some provinces also the other provisions have merely been observed in the breach, but in certain parts, as in the neighbourhood of Verona, Vicenza and Mantua, Leonardi and others of a like courage saw to it that the law did have salutary effect. Ample warning of its demands was given to all producers and dealers, and the advantages to the viticulturists of a proper observance were repeatedly stressed. In consequence, Leonardi says that in the spring of every year not only do notifications as to stock come from nurserymen but even from viticulturists themselves, who may eventually have some rooted cuttings or wood for sale.

So much for the nursery products. The question of the mother wood has always been more difficult. The mother plants grown merely for supplying wood are easily known, notification being simple and straightforward, but naturally many viticulturists have American stocks on which they are intending to graft the coming year for their own use, but from which they may equally well supply wood to the persuasive dealer in the winter at an immediately remunerative price.

Again, official dealings with viticulturists who at least will not willingly hazard their own means of livelihood have generally been simple, but the control of the dealer has proved a tougher problem.

According to law, he is asked to fill up a form at a time when he can quite honestly say he does not know the extent of his business, which will vary according to the season and to the immediate prosperity of the viticulturist, &c.

He buys and sells over a wide area and deals with many nurserymen and many viticulturists, and it is very difficult to prove definite fraudulent intent against him. The viticulturist is in a hurry, does not want to be bothered with the filling in of forms, taking of samples and the like. The temptation is too great and viticulture suffers.

Only in certain provinces has proper use been made of the provisions for inspection by government officials. Leonardi suggests that inspection must take place in the growing season and must start with the mother plants. The following state of affairs may be found :—(*a*) Mother plants are mixed both as to pureness of variety and as to vigour ;

(*b*) varieties are pure but are mixed up ; (*c*) plants are wrongly named but otherwise suitable ; (*d*) plants are correctly named, healthy, and planted in separate varieties.

For honest commercial purposes only nurseries showing the last characteristics can be depended upon.

Inspection of grafted stock in the nursery demands three visits : (1) during grafting, (2) during planting for the marking of certain plants, (3) later to control the marked plants. Such inspections in the case of numerous small nurseries spread over a wide area are practically impossible. The opportunities for fraud are still utilised, and a proposal actually brought before the Chamber that nurserymen should be expressly prohibited from producing and dealing in American vines, although not accepted, drew attention to the necessity for further legislation.

Results of Inspection.—Normally speaking, no mention is made of the certificate which the dealer should possess at the time of the sale, and it remains in the archives quite useless. Leonardi shows that in the provinces of Verona, Vicenza and Mantua, inspection certificates, giving useful information are actually produced at sales. These certificates show how the actual wares correspond with notifications. To quote an actual example in Leonardi's district from certificates concerning grafted rooted cuttings :—

(*a*) Well kept and sufficiently healthy looking, but without any trace of wild shoots from the rootstock, which might indicate the American varieties.

(*b*) Condition satisfactory ; does not contain grafts on 41B as notified ; several wild shoots on other varieties indicate that these have been named correctly.

As stated above, the taking of samples is not a general custom. If this were done some time in the winter, the identification of the American wood would easily be made (in the case of a graft all that would be necessary would be the breaking of the joint and the planting out), and the viticulturist would benefit tremendously ; all the sting, moreover, would be taken out of the practice by its generalisation.

Leonardi's suggestions in the present state of the law and custom are :—(1) Buy within the areas controlled by your own anti-phylloxera consorzio ; (2) apply to this body for advice, or failing this, insist on seeing the vendor's certificate of inspection ; (3) insist on a guarantee of genuineness ; (4) reserve the right to make inquiries ; (5) never buy in the market.

In the three provinces named, which are certainly among the most important viticultural centres in Italy, where also more has been done to prevent fraud in American wood than elsewhere, the following are the figures of the production of mother plants and of grafts notified since 1923 :—

	Mother Plants.	*Grafts.*
1923	46,000	1,200,000
1924	43,000	1,250,000
1925	37,000	1,400,000
1926	25,000	1,300,000
1927	20,000	1,900,000

These figures are more than suggestive. The tremendous increase in grafted cuttings, coupled with a large decrease in mother plants, shows that the nurseryman who originally produced mother plants either lacks capital or has found that it is not sufficiently paying, while the producer of rooted cuttings, who needs far less capital, as he does not leave part of it in the ground all the year, is very much alive to the demand for American wood and spends part of each winter searching for it and labelling it to suit local taste and lack of knowledge.

Italian viticulture has, then, large numbers of keen, shrewd, capable producers of rooted stock, who nowadays, possibly against their inclinations, are forced to buy American stock by hook or by crook or go out of business ; it has a decreasing number of private producers of the necessary American wood and a large number of official nurseries with room for extension and all facilities for producing adequate raw material, but at present somewhat crippled by lack of funds. Leonardi suggests that a law is required making it illegal for anyone other than a definitely recognised state or official organisation to deal in American wood. Here is a stroke at the root of the matter and a means of safeguarding the future.

The example of France and Italy, and the disasters that have befallen them in reconstructing their vineyards on American stock should facilitate the avoidance of these disasters in the vineyards of the Empire.

Pure and tested stock can be obtained, and a viticulturist who does not obtain them is courting disaster.

The choice of scion and of rootstock cannot be too careful: their mutual effect is discussed in the following chapter.

Types of Graft.

Actual methods of grafting are numerous and nearly every year some new method is advocated only to sink into oblivion after prolonged trial.

Pre-eminently the two most important types of graft practised through the whole of France and Italy are the cleft graft and the tongue or whipgraft (generally known on the continent as the English graft). It is on adaptations of these two that the vineyards of Bordeaux, Burgundy and Champagne are based and in the viticultural nurseries in Italy, apart from experimental work or exceptional conditions, one of these methods is always used.

Rooting Capacity.

The careful practising viticulturist has been wont to pay considerable attention not only to planting or grafting what he supposes to be true varieties but also to using only such individuals of those " varieties " as have shown consistently good cropping power.

Sometimes, however, he finds that a large number of his cuttings although apparently all of one variety and otherwise identical do not root so well as the rest.

Winkler[89] in his publication of January, 1927, gives the results of his experiments into the influence on the number of cuttings which rooted and on the quality of the rootings exerted by (1) the starch content of the cutting as indicated by the iodine test, (2) the time of planting, and (3) treatment with oxidising agents.

To determine the influence of starch content, cuttings of Sultanina were collected from several of the grape-growing sections of the State of California. Freshly cut ends of 200 cuttings were then tested by immersion for one minute in a 0·2 per cent. solution of iodine in potassium iodide.

The number of rootings of the cuttings showing a relatively high starch content was 264 per cent. of that of the cuttings containing little starch.

As regards time of planting, during the seasons of 1924 and 1925 lots of 200 cuttings each were planted at varying intervals from December of the previous year to May. Early planting was found to improve the development of the cuttings through its effect on the time of beginning of root formation.

The stimulation of root development was tested on 50 cuttings of each variety, the greatest stimulation being achieved by a 24-hour treatment with the following range of solutions :—

·001 — ·001 mol. $MnSO_4$, $Mn_2 (SO_4)$, $Mn_2 (SO_4)_3$, $K_3Fe (CN)_6$, and iodine, ·01 — ·001 mol MnO_2, $Fe Cl_3$, and Na_2O_2, and ·1 — ·05 mol. H_2O_2 and $K Mn O_4$.

Oxidising reagents hastened both callus and root formation and improved the rooting of cuttings that root with difficulty. Treatment with oxidising reagents resulted in marked increases in the relative circumference of the cuttings and the average total length of top growth at the end of the first season in the nursery.

The development of the treated cuttings appeared to be more vigorous than that of the untreated throughout the growing season in the nursery.

There appeared to be a greater stimulation of root growth at the base of cuttings by the reagents whose formulæ show oxygen than by those whose formulæ do not, when the cuttings are rooted in the solutions of the reagents.

Possibility of improvement within varieties.

Bioletti[4] in 1926 notes his own remarks in 1906 on the establishment of vineyards of pedigreed vines, that in such a vineyard each variety might gradually be brought up to its highest possible bearing capacity by grafting all the vines of each variety with cuttings taken from that vine of the same variety, which has shown the best and most regular bearing qualities during a term of years. He quotes, moreover, the advice of the Department of Agriculture of Victoria in its unnumbered circular of 1924 that "In order to secure prolific scions, the best individual vines in a block of any given variety should be carefully marked—quality and quantity of fruit, as well as general health and vigour, are the essential points to be considered in the selection of these scion-bearing vines, which may best be carried out immediately before vintage. Only fruit-bearing canes on the vines thus selected should be used as scions."

Bioletti considers that "this advice is evidently based on *a priori* reasoning from false analogy." The difference in egg production of two hens of the same breed is analogous to the difference in productiveness between two seedlings and not two clones of the same variety. The *a priori* assumption should therefore be that any bud taken from any vine, say of Muscat of Alexandria, will produce a vine having all the possibilities of any and all vines of this variety. Thus a bud from a vine which has never borne a crop is just as likely to give a heavy-bearing daughter vine as a bud from a vine of the same variety which has a long record of large production. The onus of proof lies with those who maintain the contrary.

Bioletti in summarising and drawing conclusions from investigations started in 1910 at the Kearney experiment vineyard and continued at the Davis experiment vineyard until 1925 gives *inter alia* the following details :—

> It is generally recognised that the use as planting stock of a bud cutting or rooting which is well grown and well nourished gives the best results. Opinions differ as to whether vines from weak stocks which grow will finally equal vines grown from strong stocks.
>
> To investigate this question an experiment plot of 1,200 Muscat vines was planted at Kearney in 1911 with rootings grown from stock of unselected vines rooted in a nursery in 1910.
>
> In 1920, cuttings were taken from the 115 most productive vines in this parent vineyard and from the 86 least productive. These cuttings were rooted in a nursery at Davis.

In 1921, 627 vines were planted at Davis from these rootings. Of the rootings of high-yielding parentage, 452 were planted in four groups of three rows each and one group of one row ; and of the rootings of low-yielding parentage 175 were planted in five groups of one row each, alternating with the groups of high-yielding parentage. All rootings were carefully graded and arranged in planting according to quality, i.e. size and perfection of form. The arrangement was such that (*a*) the vines of highest yielding parentage were contrasted directly with the vines of lowest-yielding parentage, and (*b*) the complication of vigorous vines growing near weak vines was avoided.

No correlation was found between the crops of parent vines and the crops of progeny vines.

From the six highest-yielding parent vines were grown 22 progeny vines. Not one of the nine highest-yielding progeny vines was among these 22.

From the five lowest-yielding parent vines were grown 11 progeny vines. Not one of the nine lowest-yielding progeny vines was among these 11.

Bioletti is led to the following conclusions :—

Exceptionally large and well formed vine rootings developed more quickly and produced a full crop one year sooner than ordinary good rootings.

The differences in bearing represented simply differences in rapidity of development, and they almost disappeared with the third crop. With very inferior rootings they might never have disappeared, especially where rootings of various degrees of size and vigour were planted together.

In such a case the weak vines would be likely to be permanently inferior owing to competition with their more vigorous neighbours.

Mass selection of vine cuttings on the basis of the yields of the parent vines was of no value in improving or maintaining productivity.

The attempt to increase the bearing of a variety of vine by the selection of buds from a parent vine, which has been distinguished by continuous and heavy bearing superior to that of the average or of any of the vines of the same variety but which shows no other distinguishing character, is fruitless.

The attempts of nurserymen and others to preserve or to improve the productivity of clonal varieties of fruit trees by bud selection based exclusively on yield records of the parent plants would be wasted efforts if applied to vines.

Bioletti considers that the conclusions drawn by him are not incompatible with the experimental results of M. B. Davis described in the latter's : "The possibility of the transmission by asexual propagation of the high-yielding ability of individual apple trees." *Scientific Agr.* 2 : 120–124, 1921 ; nor with those of Shamel, Pomery and Caryl in "Bud Selection in the Washington Naval Orange," *Jour. Hered.* 16 : 371–374, 1924.

III. THE INTER-RELATION OF ROOTSTOCK AND SCION.

The opinion of the expert growers of Bordeaux, which is typical of progressive growers everywhere in Europe, is that American stocks—

Have not necessarily any ill effects on the quality of the must yielded by the scion.

Tend to increase the product of the scion.

Have shorter lives, as far as those in general use at the present time are concerned, than the native vine, i.e. 25–30 as against 80–100–150 years.

Have come to stop.

But wherever the writer has had the opportunity of talking with commercial viticulturists in France, Germany, Italy or Switzerland, they have always declared that the rootstock has the greatest possible *influence* on the scion, that, say, Chasselas doré will produce very *differently* on Riparia Rupestris No. 3309 and on Berlandieri, both in quantity and in quality of grape. It may be that on one variety of rootstock there is a distinct tendency to disease which is absent on the other. It may even be that this phenomenon is always seen when one particular rootstock is used with a particular scion, whereas in the case of another rootstock it appears only under certain conditions of climate, soil and environment, and when the rootstock is used under these or different conditions with other scions.

This merely emphasises the point that in grafting vines the double task must be faced of suiting, not only the rootstock to the soil, but the scion to the rootstock—a rootstock, moreover, of a variety which is not so easily suited as is the old vinifera type.

The reason for affinity between stock and scion or the lack thereof is not yet solved and actual trial under specified conditions can be the only safe criterion in each case.

Affinity.[71]

The viticulturist is interested, in the writer's opinion, not as to whether the scion or stock, if eventually relieved of each other's presence, will remain influenced in any way, as having suffered the fixation of some morphological change or other, since he will not be affected thereby, but as to whether they are influenced by each other in the actual state in which they will be of use to him, and if so, in what way.

That such an influence exists would now seem to have been proved. This influence depends, according to Perold[64], on the affinity between the two vines or in other words on the relationship existing between the "Functional capacity of absorption," *Ca* of the stock and the "Functional capacity of consumption," *C'v*, of the scion. The ideal relationship for the object of normal growth would of course be Ca = C'v, any variation from this causing abnormalities in growth, which may or may not be advantageous. Such abnormalities would be on the same lines as those caused by differences in climate, soil, manuring, &c., and would therefore not become fixed.

Perold's account of the practical results of this theory is very clear, and he definitely refuses to follow any theory beyond its logical conclusion. Non-setting and millerandage are apt to occur in consequence of the use of too vigorous stock such as 1202, Rupestris du Lot, Aramon, &c. In lime chlorosis (*see* page 50) both increased and lessened chlorosis have been determined as a consequence of grafting, while sudden death or "apoplexy" is definitely more frequent in grafted than in ungrafted vines. As Ca generally >C'v, so the plant lives, as it were, in moist surroundings and is accordingly more susceptible to cryptogamic disease. Daniel quotes many instances of this.

It has been suggested by the anti-grafters, that, sooner or later, graft-hybrids are likely to form, or that there will be such an exchange of properties that the whole character of the scion and of the rootstock will be altered. Thus, a chlorosis resistant rootstock, e.g. Berlandieri, grafted with a vinifera variety subject to chlorosis will eventually itself become subject to chlorosis and that, similarly, a phylloxera-resistant stock will eventually become non-resistant to phylloxera.

Experiments at Montpellier and elsewhere by Ravaz and others, have at least established the fact that, if such is ever the case, it is of extremely rare incidence. Viala and Pacottet, speaking of the supposed greater liability to mildew, oidium and black rot of grafted vines, point out that such is entirely unproved by the facts, and that, seeing that the rootstocks are naturally more resistant to these diseases, any effect would be more likely to be in the

opposite direction, i.e. in rendering the scion more and not less resistant. The latter suggestion would appear to be strengthened by the fact that in direct producers, formed by crossing American and vinifera varieties, greater and not less resistance is normally obtained.

A fact of which the School of Daniel made the most, is that although Riparia growing alone is not normally disastrously affected by chlorosis, it may become so on being grafted with a vinifera variety with the consequent death of the grafted plant.

Couderc, as quoted by Daniel[29], says: "The ungrafted Riparias for instance, often remain fairly green, and in the end grow fairly well in most limestone soils in which they at first turn yellow. It is only after being grafted that they become so chlorotic as to die. The chlorosis is stronger or weaker according to the variety used as scion."

This then is a case where the rootstock is definitely badly affected by the scion. The natural tendency of the rootstock to suffer from chlorosis is aggravated by the imperfect affinity of the scion. Perold agrees as to this ill-effect observed, but notes, with regard to Daniel's general assertion of the ill-effects of grafting, that grafting may also have the effect of increasing the stock's resistance to lime chlorosis and so extending its area of adaptation. Thus Herbemont, which soon becomes chlorotic in limestone soils, remains green when grafted with Clairette. It is also known by experience that just as a phylloxera-susceptible variety can by grafting be enabled to live in infested ground, so difficulties of humidity, drought, and even the incidence of fungus attacks, may be overcome for vinifera varieties by grafting them on suitable rootstocks, e.g. Othello grafted is found to escape the brown rot to which it is subject on its own roots.

Viala and Pacottet are of the opinion that the characters of both lime chlorosis and phylloxera resistance are absolutely fixed, despite an instance which they themselves gave tending to disprove the first contention. Many of Daniel's theories appear indeed to be based on other material than vines, but Perold's own experiments and observation certainly show that phylloxera-resistance in rootstocks is sometimes influenced by grafting, instancing the destruction by phylloxera of 100,000 vines grafted on Aramon Nos. 1 and 2, during the last six years at the Cape.

The question of specific variation resulting from grafting is an extremely thorny one in which experts differ to a marked extent. Perold and Tribolet found that Muscat of Alexandria grafted on Herbemont in a black peaty soil showed a creeping habit of growth, whereas the same grafted on Jacquez under the same conditions showed the normal habit.

The angle of geotropism of the rootstock's roots can also be altered by the scion, becoming steeper or shallower. Daniel[29] gives instances of other effects of grafting, e.g. on the leaves, on taste, &c. These are quoted by Perold without comment.

The effect of grafting on resistance to frost is not yet established (*see* Chap. VII).

Influence of Rootstock on Crop.

Experiments are continually being made on the quantity and quality of crop produced by grafted vines.

Quantity.—Given a vigorous stock that suits both soil and scion the grafted variety will give larger crops than on its own roots. Examples of this were shown to the writer by Prosperi at the Velletri viticultural station near Rome, who is of the opinion that even though the life of the vine is shortened by grafting, at least its yearly return on capital during that life is greater.

Quality.—A large crop does not necessarily mean a crop of poor quality, a point on which stress is laid by Paulsen[63] and Maggioni in their account of the influence of the rootstock and of other factors on the quality of wines in Sicily. In this work they discuss their examination of the alcohol content of the wine made from several varieties such as Grillo, Catanese and others as differing according to the rootstock on which they were grafted. Among their conclusions, the following are worth noting :—The quality of wines is due partly to intrinsic value, partly to extrinsic or to environment and conditions of cultivation ; quantity in no way prevents quality when dealing with stocks which are naturally very productive, and are planted in fresh, fertile soil ; variations in alcohol content due to season differences range from 1°·3 to 3°·4 according to the rootstock, and are much smaller in dry than in wet years ; the variations according to soil are more constant and are smaller as regards each rootstock ; the differences due to the different nature of the rootstocks are less than either of the above and can be masked to the palate by other constituents. The quality* of the product, at least up to a certain point, is in inverse relation to the resistance to drought (*see* page 49) of the rootstocks and to their vigour and to the consequent delay in ripening of the grapes, in fresh soils and in rainy years ; the contrary holds good under contrary conditions.

The five rootstocks under investigation for five years are classed as follows for quality of product :—Berlandieri × Riparia 420-A, Aramon × Rupestris G.N.1, Mourvèdre × Rupestris 1202, and Rupestris × Berlandieri 17–37, Rupestris du Lot. Rootstocks yielding the most constant quality of crop were 17–37 and 420-A. The crop from Aramon × Rupestris and Rupestris du Lot varied much more from year to year.

Carpentieri[12] in his report on the causes influencing the ripening of grapes and the composition of wine gives details of the different composition of the wine of grapes grown on their own roots, especially Sangiovese and Aglianico, and on about 20 different rootstocks. He considers that no permanent conclusions can logically be drawn in one or the other direction from the figures quoted, but he points out that they prove that very great influence is actually exerted.

Some of the most careful and satisfactory experiments have been carried out continuously since 1911 by Faes and his assistants of the Swiss Viticultural Station at Lausanne.[34, 35] It is hoped that even fuller results will have been gained in 1929.

The writer considers that the method and results of these experiments merit considerable attention.

The experimental fields are seven, namely, Mont sur Rolle, Morges, Epesses, Vevey, Aigle, Arnex sur Orbe, Grandson—all being planted between 1906 and 1909.

The vines, except at Arnex sur Orbe, are planted at a distance of just over 30 in. from each other with an interval of 48 in. between lines. Each plot is of about 27 ares, or ⅝ acre. This is divided into three sections of which the largest is planted with Chasselas fendant, grafted on various rootstocks, there being between 80 and 100 examples on each variety of rootstock. The second is filled with direct producers. The third is planted with vinifera varieties on their own roots for purposes of control and of manurial, cultural and pruning trials.

The following analytical facts are determined :—

Specific gravity, Oechslé degrees, Potential Alcohol vol per cent., Total extract gm. per litre, Sugar assimilated gms. per litre, Non-sugar extract gm. per litre, Total acidity gm. per litre, Tartaric acid gm. per litre, Coefficient of maturity $= \frac{\text{tartaric acid} \times 100}{\text{total acidity}}$, Return in crushed grapes per plant, Sugar assimilated per plant.

* The conclusions refer to the particular material on which the authors were working and cannot necessarily be applied generally.

The following are quotations from their summarised observations on results from 1911–1924 :—

> We have now had 15 years continuous observations on rootstocks in every part of our experimental plots. Another five years will enable us to feel ample confidence in reconstructing our Swiss vineyards.
>
> Generally speaking, the yields of plants on the same rootstock is very similar in every part of our experimental area.
>
> Our experiments up to date show that the substitution of new rootstocks for old was quite justifiable and also that certain of the old rootstocks deserved their place of honour. Thus Solonis × Riparia 1616 and Riparia × Rupestris 11 F. Dufour generally prove to be rootstocks productive of quantity and quality, yielding musts with a high percentage of sugar and little acid.
>
> The two hybrids Mourvèdre × Rupestris 1202 and Aramon × Rupestris 1 have lost their character in our vineyards. They produce wood and leaves, but few grapes and those of very ordinary quality.
>
> The tables show the great success of the Riparia × Rupestris 3309, 3306, 101·14 rootstocks. These with 11 F. Dufour mentioned above allow between them for the successful replanting of our vineyards. Occasional anomalies occur such as the rather high acidity produced on 3306 at Aigle and on 11 F. at Morges.
>
> Among Berlandieri hybrids used on difficult soils, where products of quality are desired, Chasselas × Berlandieri 41 B is specially worthy of note, giving both quantity and a high sugar content. It is followed closely by Berlandieri × Riparia 157.11.
>
> The influence of the rootstock on quantity and quality must not be exaggerated. Manuring, cultivation, the time of pruning and training the vine, the climatic conditions of the year have a much greater influence on the crop than the choice of rootstock. The influence of the rootstock certainly exists, but it is relatively variable.
>
> A single rootstock cannot be recommended as suitable for all conditions in our district. One variety will suit one set of conditions, one another.
>
> We have found that a rootstock may give the greatest yield in the first years only to be overtaken later by other competitors, which in their turn may yield pride of place to others, whose acme of production is late. Reconstruction of the vineyards affords the frequent possibility of adopting such a rootstock as may influence in a favourable manner, both qualitative and quantitative, the product of the variety used as scion.

The problem of the viticulturist is certainly complicated by the necessity for grafting. Thus it is generally found that grafted stock will, without pressure, give a higher annual yield than vines growing on their own roots. This, however, being a highly artificial process cannot always be carried on without detriment to both stock and scion. Sometimes, the only result may be that the vine will produce say in 25 years what an ungrafted vine might produce in 40, and will then decline and have to be replaced. In other cases—and naturally as reconstruction becomes more and more general so they become more frequent—signs appear after a few years of one or other of those non-parasitic disturbances (*see* page 45) which, if left untreated, may result in death. Very frequently the temptation to produce heavily in view of the apparent excellent health of the plant is too great, and the results are disastrous.

There can be no hard and fast rule in a case where the factors interacting are so numerous : soil, climate, rootstock, scion, cultivations, manuring and pruning are perhaps the most important, and they ring the changes sometimes in surprising fashion.

A Jacques stock, normally very resistant to phylloxera, may be found perishing from that disease in consequence of the excessive production of the scion above, or root rot may set in on healthy roots weakened by similar efforts.

The viticulturist can only exercise care in selecting his varieties, his ground, and his methods of growing the vines, watching against overproduction, which includes too early production by young vines, attending to manuring and drainage and keeping an eye open for the first signs of any physiological trouble.

"The normal healthy life of the plants depends upon a state of equilibrium, which must be maintained as far as possible. A disturbance of it, for instance by over-production, endangers the plant's whole life."[64]

Wherever reconstruction takes place, very great help can be obtained from experiments in grafting carried out in other countries, but it must never be forgotten that conditions must differ whether to a small or large extent in the two lands. Hence arises the necessity for the establishment of experimental vineyards for the purpose of testing out over a long period, 20–30 years, the varieties of rootstocks and scions which the experience of other districts or countries seems to recommend as suitable for planting in that particular region.

Many other problems could be undertaken in such stations throughout the life of the vines, and advice could be given by the officers in charge to viticulturists in the district faced by problems arising from planting for the first time or planting grafted stock new to the district.

The more common European Rootstocks.

The writer found that in the more important districts visited by him the following rootstocks were most generally used :—

1. *Italy*.—In Chianti the rootstocks specially recommended are those belonging to the Vinifera-Berlandieri and the Berlandieri-Rupestris group.

Prosperi[68] in suggesting the most suitable table grapes and rootstocks, notes :—

(1) That Panse precoce has good affinity for Berl. × Rip. 420A. and for Aramon × Rupestris G. No. 1, its fruit ripening earlier on the former but being more abundant on the latter.

(2) That Baresana possesses good affinity for Berl. × Rip. 420A. ; Uva Regina especially for Ar. × Rup. G. No. 1, and for Rup. × Berl. 301A ; Corniola for Berl. × Rip. 420A and 34E.

(3) That Razaki rosso should be grafted on 3309 or Ar. × Rup. G. No. 1, and Almeria on Ar. × Rup. G. No. 1, and on Rup. × Berl. 301A.

(4) That for muscats the rootstocks to be preferred are Rupestris Metallica and Aramon × Rupestris G. No. 1. Muscats have little affinity for American stocks in which Riparia or Berlandieri blood predominates, though in calcareous soil Muscat of Terracina can be successfully grown on Berl. × Rip. 420A.

In Venetia the usual rootstocks are : Rupestris du Lot,* Riparia × Rupestris 3309 and 101·14, Riparia × Berlandieri 157·11, Rupestris × Berlandieri 17·37.

* Rupestris du Lot is also the most generally used rootstock in the Almeria vineyards of Spain.

2. *France.*—Bordeaux. The rootstocks commonly used include the following :—

(1) Ancient types such as Noah, Clinton, Jacques, in places where phylloxera is not a danger.

(2) Riparia Gloire de Montpellier in deep alluvial soils. Rupestris, for deep gravelly soils, but takes badly ; is good for Cabernet Sauvignon.

(3) Rupestris hybrids.

Rip. × Rup. 3306 in fresh argillaceous soils.
,, ,, 3309 in deep soils.
,, ,, 101·14.
Cordifolia × Rup. 107.
Vinifera Rupestris × Aramon Rupestris Ganzin No. 2.

(4) Americo-American stocks—various.

(5) Vinifero-American stocks. Cabernet Berlandieri 333 E.M. Chasselas Berlandieri 41B.

Burgundy. The rootstocks vary according to the lime content of the soil, being generally :—

In soils containing	10–15 per cent. Ca CO_3	Riparia Gloire de Montpellier.
,, ,,	15–30 ,, ,,	Rip. × Rup. 3309 de Couderc.
,, ,,	30–40 ,, ,,	Berl. × Rip.
,, ,,	40–60 ,, ,,	Chasselas × Berl.

Champagne. All new planting is now done on some type of Berlandieri owing to the heavy lime content of the soil.

Generally speaking, Aramon, a most popular French variety, has been found to have much more affinity with Riparia and its hybrids such as Rip. × Rup. or Rip. × Berl. than with Rupestris and its hybrids, hence the marked preference among French vine growers for Riparia and Berlandieri rootstocks.

3. *Germany.*—Dr. Meiszner[51] considers the following rootstocks most suitable for use in German vineyards :—

(1) *Pure Americans :* Riparia Gloire de Montpellier and Rupestris du Lot.

(2) *Americo-Americans :* Riparia × Rupestris 3309C, Rip. × Rup. 3306C, Solonis × Riparia 1616C, Berlandieri × Riparia 161.49C, Berl. × Rip. 157.11C, Berlandieri × Riparia Teleki 8B.

Berl. × Rip. Tel. Selektion Kober B.B.

(3) *Vinifera-Americans :* Aramon × Rupestris Ganzin No. 1, Mourvèdre × Rupestris 1202C, Aramon × Riparia 143B (Millardet and Graffet), Riparia × Gamay 595 Oberlin.

All the above, except the whole of group (2), were included in those tested at the Leideck experimental fields between the years 1891 and 1922, on whose merits Biermann[2] writes as follows :—

The rootstocks which have hitherto proved most suited to the types of soil encountered in the Rhineland are :—

For slaty (" schiefer ") soils : Riparia IG., Riparia × Rupestris 10114 M.G., Rip. × Rup. 13G., Cabernet × Rupestris 33a M.G., Aramon × Rupestris I Gz., Aramon × Riparia 143B M.G.

For loam soils : Riparia IG., Riparia × Rupestris 101.14 M.G.

For loesz soils : Riparia IG (soil of low lime content), Cabernet × Rupestris 33a M.G., Aramon × Rupestris 1 Gz.

For gravel soils : Solonis × Riparia 1616C.

Drought resistant rootstocks.

Perold cites Rip. Gloire, 106·8, Rup. du Lot and 1202 as being especially resistant.

Dalmasso[27] in his monograph on viticulture in Cyrenaica considers that the rootstocks which are most likely to show resistance to the drought and unfavourable physical conditions of the Cyrenaican plateaux are :—Rupestris du Lot, Rupestris Metallica, Riparia × Rupestris 3309, Berlandieri × Riparia 420A, 34E, 161–49 and 157–11, Berlandieri × Rupestris 17–37, Riparia × Cordifoglia × Rupestris 106·8, Solonis × Cordifoglia × Rupestris 202–4, Aestivalis-Monticola × Riparia-Rupestris 554–5.

The same authority also notes that the rootstocks most used in Algeria are :—Rupestris du Lot 3306 and 3309, Berlandieri × Riparia 420A and Chasselas × Berlandieri 41B. The Vinifera × Rupestris hybrids are being abandoned owing to their lack of phylloxera resistance under arid conditions.

Vivet (quoted by Dalmasso) notes that Rupestris du Lot has shown itself most capable of flourishing in the salt soils of Algeria, in great contrast to Riparia × Rupestris 3306, 3309, and 101–14.

IV. PRUNING, MANURING AND GENERAL MANAGEMENT.

The writer does not propose to treat in detail the general management of vines as regards pruning, training and ordinary cultivation practice.

Systems are legion and adaptations are, in general, suited only to particular conditions in particular places.

Training.

The two limits are seen in the Médoc Vineyards, the crops of which nearly touch the ground, and in those of Aversano, a district north of Naples, where the longest ladders are necessary to pick the fruit hanging in the topmost branches of poplars.

All manuals of modern viticulture devote ample space to this subject and to that of pruning. In English the inquirer has the choice of Perold's *Manual of Viticulture*[64], Bioletti's *Pruning of the Vine in California*[3] and other articles, Laffer's *Pruning of the Vine*[43]—to mention but a few—to guide him.

Pruning.

Bioletti sums up the main objects of pruning as follows :—To give the vine a suitable form and to conserve this form, and secondly so to regulate the bearing that the maximum quantity of crop may be obtained for a long series of years at the minimum expense.

Work by Winkler[88], published in 1926, tends to show that modern methods of pruning may not always achieve the desired result.

In his experiments he tested the respective effects on Muscat, Monukka and Alicante Bouschet of—(1) No pruning and no cropping, all bunches being removed before blooming; (2) No pruning, part cropping; (3) No pruning, total cropping; (4) Normal pruning, no cropping; (5) Normal pruning, total cropping; (6) Severe pruning, no cropping; (7) Severe pruning, total cropping. Moreover, to determine the response of newly established rooted vines to pruning, 400 selected cuttings each of Petite Sirah and Gros Colman were planted in parallel rows in a uniform soil, and at the end of the first season spaced uniformly 18 in. by 6 ft. The effect of not pruning and of pruning back to two buds was then noted.

He came to the following conclusions :—(1) Dormant pruning reduces capacity (capacity is defined as " the quantity of action in respect to growth and production of which the

vine or part of the vine is capable "). (2) Bearing reduces capacity less than pruning. (3) Non-pruned vines produce more fruit. (4) Non-pruned, part crop vines produce better fruit. N.B.—The non-pruned, part crop vines produced grapes of normal sugar content; the increase in the weight of crop has decreased the sugar content of the fruit in the non-pruned all crop vines. (5) Pruning decreases germinability of pollen.

Manuring.

Modern vine manuring is largely based on Muntz's careful and minute examinations into the amounts of nutrient material removed from the soil by the vine.

Rules which apply to the manuring of other plants apply equally well to that of the vine, and, from an economical standpoint, two facts must never be forgotten: first, that the complete neglect of one particular element of food may lead to the failure of the plant to assimilate even over-ample doses of other food elements, a danger stressed by Chancrin[20], and that on the other hand, although one may be able to raise the yield even of good wine to phenomenal heights, such a course may be uneconomical, and, in addition, the vine may become exhausted.

Durand[31] suggests that from the determination of the weight of the prunings made can be calculated the weight of foodstuffs abstracted and thus the amount which must be returned to the soil in the shape of manure.

Carpentieri[12], in his monograph on the causes affecting the ripening of grapes and the composition of wine, considers the tremendous range of difference existing between different wines even of the same area. In Italy out of some 4,236,000 hectares under vines, only 832,000 are under vines alone, the remainder being under mixed crops. This implies that the vine is not always grown in positions which suit it best.

He considers that climate has the greatest effect on the composition of the wine, but that manuring and cultivation also affect it in smaller degree, a difference of 8 to 10 degrees in alcoholic content being found between wines from grapes grown in one and the same commune, but subjected to different cultural treatment. The cultivation and manuring of the associated plants naturally has a very great effect on the growth and product of the vines with which they are growing.

Ravaz and Verge[75] are led by experiments at Montpellier to consider that the colour of the foliage is a good guide to health and to the food requirements or deficiencies of the vine. They conclude that the intensity of the green colour of the leaves up to the moment when growth stops is related to the ratio *Nitrogen : Water* of the soil, comprised within the limits which assure the growth of the plant. After the cessation of growth the green colour depends on the ratio *potash : lime.* This potash may be added in the form of KCl, K_2SO_4 or sylvinite. It is uncertain whether ashes have the same effect. Sylvinite, which may not however take effect the first year, is extremely efficaceous, especially when applied at long intervals. A vigorous rootstock, moreover, may have the same effect as potash in this respect, hence the effect of the latter will be most noticeable on less vigorous vines.

The most suitable form in which fertilising elements should be given varies with varying conditions.

The different viticultural journals are continually giving interesting accounts of such trials as are carried out throughout the vine areas on different systems of manuring, but there is great divergency of method, and it is doubtful whether the rather general conclusions deduced are always reliable.

Those of Chauzit[24] on potassic and nitrogenous manuring are typical of the more careful type of experiment so described.

The experiments were conducted at Grangeneuve in Hérault, France. The soil is described as of a heavy, calcareous nature, and the climatic conditions obtaining in summer are noted as hot, with considerable wind and drought.

The amount of potash given yearly in different forms, i.e. 134 lb. per acre, and the vines to which applied, i.e. Aramon grafted on 3309, are noted.

The five years averages 1923–1927 are given as showing that the best effect was got with carbonate of potash, followed by nitrate, sulphate, chloride, sylvinite being a poor last.

Nitrogenous manures in order of effect on Terret-Bourret grafted on Riparia are in the same way placed in the following decreasing order of effect : dried blood and nitrate of soda, marc and nitrate of soda, dried blood, nitrate of soda, marc + sulphate of ammonia, nitrate of lime, sulphate of ammonia, cyanamide.

The conclusion reached by Chauzit is that under the conditions obtaining at Grangeneuve the carbonate is the best potassic manure, but that for economical reasons the sulphate or nitrate should be preferred, while nitrogen has the best effect on the vine when given in the form of a quickly decomposing organic manure in association with the nitric nitrogen of nitrate of soda.

Such results might well be quite different under different conditions of soil, climate and stock, and the amount of divergencies shown by the comparative figures given stresses the necessity for experimental work in every viticultural area.

The method of application of manures depends on the type of soil. In no case should any artificial fertiliser come into contact with the young vine. When the soil is shallow the manure should be spread early and cultivated in at 4 or 5 in. If a deep soil is in question, deep furrows between the rows, or holes between four vines, 18–24 in. sq., and 12–15 in. deep should be used. Throughout its growing period the vine should always have nitrogen present in available form

When farmyard manure is used, it is most economically given, say, once in four years. It does not come into immediate effect, and for its effect to appear in the same season it should be applied early enough, the old Italian proverb holding good—" Better a shovel of dung at Christmas than a cartload at Carnival ".

Perold gives certain formulæ for manuring which he regards in the light of average values to be departed from where necessary

As regards the absolute quantities of nutrients to be given annually per acre of bearing vines, presumably 5 ft. by 5 ft. square, he recommends as mean values :—Nitrogen 30–40 lb., P_2O_5 40–60 lb., K_2O 40–50 lb., the nitrogen being reduced, if growth becomes too vigorous. He also notes that when sufficient farmyard manure is not available to fertilise the vines annually, an attempt should be made to introduce organic matter at least every second year. This can be done alternatively by means of farmyard manure and by green manuring.

Ottavi and Strucchi[60] strongly recommend that the planting up of a vineyard shall be preceded by a green crop, small-seeded horse beans or vetch for heavyish soils, lupins or crimson clover for lighter soils. This is cut and allowed to rot during the preparation of the ground, and, when turned in, should provide all that is necessary for the young vine during its first two years.

They also stress the necessity for local experiments in every case.

Perold recommends green manuring in the absence of farmyard manure, especially with peas or gousblom (*Cryptostemma calendulaceum*). The latter was successfully tried by Malherbe on the Stellenbosch University farm. It will give considerably more, in fact four times as much, dry vegetable matter as peas, and will efficiently prevent the loss of plant food from the soil in winter. In soils lacking lime this can be introduced with advantage in manures given to the green crop. Oberlin in Alsace found that gypsum had an excellent effect as a mobiliser of soil food resources.

Ross and Niekerk[77] also recommend green manuring, advising that the crop should be cut when in full bloom, and should then be left for two or three weeks, after which it should be incorporated with the soil by cross ploughing or cultivation.

Pacottet considers the practice a useful one in default of farmyard manure, in which case the crop should be well slagged.

Green manuring may therefore take the place of farmyard manure when not available, or may be used in such volcanic soils as, for instance, are found in the Roman Campagna or on the slopes of Vesuvius, whence come the Lacrima Christi, Capri and other famous wines of Southern Italy, but it is not so suitable where rapid growth of the green crop is prevented, as in Germany, by a protracted winter.

Other useful residue manures are cakes from the refuse of oil extraction factories. Such are sesame, rape, ground nut, decorticated nut cake, dried blood, etc.; they are generally unbalanced and highly nitrogenous.

Pacottet[61] notes the fact that on the irrigated lands of Hérault, Aramon produces some 2,250 gallons of wine per acre. This is, as might be expected, a good wholesome wine of no great character. Such a production is only rendered possible by the addition of water which makes the foodstuffs in the soil available. (*See also* page 47.)

The French waste nothing, and hence French winegrowers strongly insist on the return to the soil of the prunings and of the marc. This after extraction should be mixed with Cao or mineral phosphates and used as a manure, thus avoiding serious waste. It may also be fed to stock and so returned to the ground. It contains twice as much nitrogen and about the same amount of potash and phosphates as farmyard manure.

The old practice of economising manure by the introduction of the débris from ravines containing washed down organic and mineral matters has now given place to the addition of compost material formed by the heaping in layers of various organic débris, ditch sweepings, city garbage, leather waste decomposed in the presence of lime and retaining the ammonia thanks to the addition of sulphate of iron. Their effect is excellent and lasting, but owing to their bulk and the expense of cartage, they are generally only used by nurserymen or table grape growers. It is worth noting that in the Rhône valley schists are thrown into the vineyard, and after decomposition in anything from six months to a year their manurial effect is noticeable. Much the same is seen in the Roman Campagna and in Tuscany; thus, in the Chianti valley, before planting the rock must be removed by dynamite, and when brought to the surface is quite hard, yet, after a year or two's weathering, it provides one of the finest vine soils possible, containing plant nutrients that become available slowly and without waste.

To give any general formula is to court trouble, so varying are climates, sites, rainfall, objects in view and cultural practices, the universal habit of experienced vine growers being to watch very carefully the vines themselves. At Chateau Livran,[45] for example, in Médoc, and at Corton Grancey[50] near Beaune, very careful note is taken yearly of vines which have been shy or have shown signs of exhaustion, and the manuring is adapted accordingly. The general rotation of manuring is adjusted to suit the case.

V. TABLE GRAPES AND RAISINS.

The main object of viticulture is the production of grapes for wine and for the table.

Wine is still, despite prohibition in the U.S.A., the chief object.

It will not, however, be amiss to consider the second purpose, namely the production of table grapes and raisins.

Varieties.

The most popular varieties cultivated in the countries chiefly responsible for the production of table grapes are :—*Spain*—Almeria or Ohanez, Malaga and the various types of Muscat : *France*—Chasselas doré, followed by Muscat, Oeillade, Alicante and Blue Portuguese ; *Algeria*—Chasselas doré, Madeleine, Muscat of Alexandria, Oeillade and the direct producer Seibel 2653 ; *Italy* (as recommended by Prosperi)—Panse precoce of early varieties ; Baresana, Uva Regina, Corniola of main crop varieties ; Razaki rosso, Almeria of late varieties ; Zibibbo and Muscat of Terracina of the muscats ; and Sultanina bianca of the pipless varieties.

The chief varieties grown for raisins are :—*Greece*—Sultana, Black Corinth and Zibibbo ; *Turkey*—Sultana, Razaki, Raisin noir de Thyra and Raisin noir de Scala Nova ; *Spain*—Malaga (=Muscat of Alexandria, Perold) ; *California*—Black, White and Red Corinths and Sultanas.

Cultural Points.

The growing of table grapes does not in its main outlines differ greatly from that of grapes destined for wine. The opinions, however, of the best European authorities on the adaptation or suitability of certain treatments are worth attention.

Professor Longo,[46] late Director of the Viticultural Station of Velletri, insists on the necessity for extraordinary care in all processes of pruning. Thus the different systems of pruning and training the vine influence very considerably the vegetative equilibrium between its different parts, the regularity of its shape, the time of ripening of the grapes, even the keeping qualities of the latter and their beauty of appearance.

Whatever the system adopted, no attempt must be made to force matters, nor must the strength of the vine be exhausted by premature bearing. There are, moreover, certain operations applicable under all conditions which conduce towards a more perfect market product.

To Longo's three essential operations Musci[57] adds a fourth, thus : artificial fertilisation, ring barking and thinning, and fourth, at least for those grown espalier-wise against the wall, defoliation.

Artificial Fertilisation.—In cases where, owing to the shortness of stamens or other reasons, many berries remain unfertilised, as in Bicane, and fall off, or, fertilisation being imperfect, small pipless berries form, as in Frankenthal or Razaki rosso, or where, as in the Hambourg, Muscat and others, ripening tends to be uneven, artificial fertilisation is recommended.

There are two methods of procedure :—(*a*) On two or three occasions at intervals of two or three days when the vine is in full flower, the bunch is taken in the palm of the hand and stroked once or twice from the base to the apex. This may be done without previous preparation, or the hand may first be fertilised by pollen from other vine flower bunches. The operation should be carried out in the warm hours, because it is then that the dry corollas detach themselves and fall more easily, and the pollen is distributed more regularly. (*b*) A flower bunch is taken from another variety containing ripe male flowers and is shaken over the bunches needing fertilisation. In the experimental station at Bari the

pollen-bearing flowers used were taken from an American rootstock Aramon Rupestris Ganzin No. 1, which is a hybrid producing a large number of flowers mainly male, possessed of abundant pollen. At Bari, this method was the more successful of the two, though for the Moscattellone (Muscat of Alexandria, Perold) both were equally efficient. Experiments on the Mouillefert system are now in progress there. This consists in running cordons of Chasselas below those of Madeleine Angevine, with a view to the fertilisation of the latter.

Ring Barking.—Perold, Ravaz, and the Italian authorities all support this practice in the case of table grapes. In the opinion of Perold and in view of experiments carried out on the Stellenbosch University farm in 1924, with Madeleine Angevine, Bicane, Olivette Blanche, Ohanez (White Almeria) and Gros Noir des Beni Abès, ring barking during flowering definitely prevented coulure in these varieties. *There is, however, no proof that it has caused a single additional large berry with seeds to be formed. . .Ring barking therefore promotes parthenocarpy to a wonderful extent but has no influence upon the real fertilisation,** at least with the varieties under trial.

The process consists of removing a ring of bark about $\frac{1}{8}$ in. wide at the time of flowering below the lowest bunch, but above such buds as will produce next year's fruit. At Bari trials extending over three years on Madeleine Angevine, Baresana, Chasselas doré and Chasselas rosé gave excellent results against coulure, though in the case of Madeleine Angevine the bunches were more dense and regular but still had small berries, a fact which bears out Perold's statement above.

Ring barking may also be carried out to obtain early ripening and for this purpose according to Bonnet[6] should take place when the berries are half grown. Bonnet, Perold and Ravaz consider that ripening may so be hastened. In Bonnet's experiments a much higher sugar content and lower acidity was found in the ringed than in the unringed grapes. At Bari, on the other hand, while ringing hastened the ripening of Chasselas rosé by 15 days and Baresana by 8–9 days, it hardly effected Chasselas doré or Madeleine Angevine at all. In this connection, Prof. Sannino's[79] experience appears to be different to that of Bonnet, and he states that " ringing retards the real or complete ripening of the grape, so that the sugar contained in ringed grape bunches is much less than that in those not treated."

Longo[46] advises against ringing in wet climates, in moist or very cold soils and for very vigorous vines, as it is liable to cause such sudden swelling of the berries as to burst the skins.

Manaresi[48] in his experiments on Chasselas bianco and Muscato bianco at Imolese, while generally agreeing with accepted theory, notes the following points :—(1) the bunches of the ringed vines had nearly all a larger quantity of small berries and of seedless berries than the others ; (2) the density of the grapes produced on ringed branches was slightly inferior, the average being 1·0552 as against 1·0638 ; (3) the grapes from the ringed vines—a normal feature in all grafted plants where the callus of the scar functions like a partial girdling—were somewhat more susceptible to cryptogamic diseases, especially to *Botrytis cinerea*, grey rot.

Of the grapes picked by him in the above experiments, he found 25·31 per cent. of the ringed grapes and 13·24 per cent. of the control grapes affected by grey rot. Bioletti[3] notes the weakening effect of ringing especially in hot climates and states that it is not practised in California.

---

* Perold's italics.

Thinning.—This practice is absolutely necessary to obtain sound, uniform bunches of good appearance for the export trade. The amount of thinning depends on the variety. Perold considers that at the Cape three thinnings should be done, the first when the berries are $\frac{1}{8}$ of an inch in diameter.

All small or bad berries, and berries which will spoil the shape are removed, and great care is taken not to touch the grapes in the second and third thinning, blunt-nosed scissors being used. Musci[57] stresses the necessity of covering the trimmed bunches after the operation by means of leaves. The amount of berries to be removed may vary from nil to two-thirds of the bunch.

Defoliation.—This consists in the removal of a part of the leaves and tendrils in the neighbourhood of the grapes. The aim is to give free access to air and light, to prevent removal of bloom by leaves in strong winds, and, in the case of grapes against a wall, to allow of the full use of the sun's rays on the wall. Care must be taken to leave enough leaves to shelter the grapes, and the process should take place in dull days and should be gradual.

Italian authorities lay stress on removing only the leaf without the stalk.

At Thoméry, in France, great attention is paid to this process, which takes place on three occasions: (1) before the thinning, (2) when the grapes are beginning to turn colour, and (3) just before ripening.

Perold stresses the necessity for removing all tendrils at the time of the first thinning. In the event of heavy rains when grapes are ripe, the aeration consequent on the process checks the advent of rot.

Early Maturity.—Apart from the practice of ring barking, there are certain other devices for promoting early maturity. At Thoméry walls covered by grape vines extend over an area of more than 120 hectares. In the streets themselves, instead of flower beds in front of the houses or strips of grass, the vine is trained, not negligently, but with the utmost care, and every use is thereby made of the sun's rays. Along the walls above the grapes and acting as shelters from rain are glass shields.

Such a system is unnecessary farther south, in the ordinary course of events, though it may be useful to induce early maturity.

Experiments are now in progress in Italy at Bari[57] and at Velletri for the hastening of maturity by means of movable glass frames, of wooden walls, and of various devices for trapping and turning to good use the sun's rays.

Ravaz[70] notes the necessity for so training and pruning the vine that the grape bunches hang vertically, a position which above all others tends to early ripening.

Actual Cultural Practice.

Algeria.—Here the area devoted to grapes both for table and wine is that of the coast. The soil is sandy or sandy argillaceous, red, light and easily worked, and the vineyards are well protected from the hot sirocco and the sea winds. Lately, however, a certain amount of ground has been yielded to vegetables.

In *Spain*[8] the vines are normally grown to a height of about 6 ft., the main stem forking into two opposite branches which again divide into two.

They are well manured with dung and artificials and the ground is kept free from weeds.

Ring-girdling and thinning are practised in some parts; artificial fertilisation is always practised in the case of the Ohanez.

Harvesting is done from the beginning of September to the third week in October. Those grapes which are picked before the autumn rains will keep from four to five months and are exported—not so those picked later.

In *Italy*[67] a great point is made of deep cultivation. The soil being worked thoroughly to a depth of 2 ft. or more—in Latium the writer has seen the soil being worked to a depth of nearly 5 ft. in preparation for table grapes. (*See also* page 49.)

When possible, rooted grafted stock is planted, but, owing to the inadequate supply of this, the normal practice is to graft on the spot, starting in mid February with the first attempt, and in the event of failure regrafting in April, May or up till mid June using ordinary whip grafting, and, where necessary, grafting twice more during the same year, *i.e.* ring grafting in July and shield grafting in August and September.

Harvesting and Keeping Table Grapes.

In *France* the best quality or luxury grapes are cultivated with the greatest care in Seine et Marne, near Fontainebleau at Thoméry. Here the grapes are grown generally on walls facing south and south-east, the west and south-west positions being reserved for Black Frankenthal.

The best are kept in cool chambers, in the dark, during the autumn, and released on the Paris market as luxury out-of-season products.

Storage Systems.—Among the points brought out by M. Charmeux[22] in his report to the first Table Grapes Congress at Agen in 1925 were the following : the dry stem method may well be used to supplement the wet stem method, and if sufficient care is taken there is no reason why the result should be grooved, mumified grapes unfit for export. He recommends hanging, wrapped in dry peat moss, and making use of refrigeration when available.

The more usual method, however, adopted in the Ile de France is the wet stem method.

In the practice of this method at Thoméry and elsewhere old vines are said to yield branches which will stand preservation better than those of younger vines—before the era of grafting vines 50 years old and more were always chosen.

Bunches must be ripe and absolutely undamaged. The best will be those farthest away from the soil, and, on young vines especially, those touching or very close to the ground, even if sacked, should be left. The heat of the sun's rays, especially on those sacked, and the August-September rains detract from their value. The lower bunches, moreover, are more indicated by their greater earliness for sale fresh on the early market.

After cutting, the bunches are trimmed and carted to the store room. The picking is done during the day and the bunches must be put in store at once.

Suitable store rooms can be formed in the subsoil where this lends itself to the purpose, as evenness of temperature is here easily obtained. The chambers are normally fitted with 1,500 to 2,000 small flasks set in tiers and tilted from the perpendicular, each flask taking from one to four bunches, the total content being some 800 to 1,000 kg. of grapes.

The best, i.e. the sacked bunches, are put in the highest and lowest tiers as needing least subsequent attention.

At the first rain, all the openings are carefully shut and the chamber is left in darkness, after burning a few grammes of sulphur, say, a coffee-cup full per 2,000 flasks.

Rivière and Charmeux consider that the optimum temperature would be about 35°·6 to 39°·2 F., though one of 48°·2 to 53°·6 F. will do.

Excessive humidity need not be feared and the hygrometer can register 90 per cent. saturation without danger.

The room is only visited when necessary for removing grapes to send to market.

Charmeux mentions other scientific processes as follows :—

(1) Preservation in carbonic acid gas as tried successfully by Sannino at the Viticultural Station of Alba in North Italy.

(2) Preservation by refrigeration in an atmosphere of antiseptic gas composed of CO_2 and a little O_2, the CO_2 and the cold preventing the growth of micro-organisms, the oxygen allowing the fruit to continue life. This method is advocated by Lescardé.

(3) Preservation by alcoholic emanations, found successful in the laboratory but at present too costly.

(4) Various methods of refrigeration. These need considerable study as to details of temperature, moisture, &c. The Congress referred to above passed a resolution that all possible steps should be taken towards the perfecting of refrigeration methods for the conservation of table grapes.

Drying of Grapes[9].

The primitive and somewhat distasteful method of drying grapes as formerly practised in Greece and elsewhere has now given way to pleasanter, more efficient methods.

At Alicante in Spain the grapes are dipped in alkali solution before drying, whereas at Malaga they are normally sun-dried without this preliminary operation. The drying of the late picked grapes may sometimes be completed in drying chambers at a temperature of 107°·6–109°·4 F.

A full account is given by Christie and Barnard[25] of the methods of sun-drying successfully observed in California.

They note that the drying ratio is regulated by the sugar content and averages $3\frac{1}{2} : 1$.

To obtain raisins of first quality, Muscat grapes should not be picked below 25° Balling (sugar content degree) nor Sultaninas below 23° Balling.

Briefly there are two general methods :—

(1) Drying untreated grapes on trays between the rows in the vineyard.

(2) Drying dipped grapes, with or without sulphur bleaching, on trays in a dry yard.

Practically all Muscat raisins and the greater part of the Sultaninas are dried in the vineyard, by the first or so-called " natural method."

Methods of Distribution of Table Grapes and Raisins.

The Spanish Government, realising in the face of growing competition the necessity for setting and maintaining a high standard, intervened in the table grape trade in 1924, forming an Official Chamber of Producers and Exporters of Grapes in the province of Almeria and fixing its rules.

No producer or exporter who does not belong is allowed to export.

The amounts to be exported yearly are settled by the Committee of the Chamber and submitted to the Government for approval.

Only the best grapes in each vineyard are passed for export, a normal proportion being about 10 per cent. of the total crop, a special proposal of the chamber and its approval by the governor being necessary for larger amounts.

The Chamber arranges for :—

(1) The uniform content of each barrel.

(2) Distribution of grapes to suit the market.

(3) Disposal of grapes remaining unexported.

(4) Appointment of an expert whose duty it is to advise and control in the vineyard, and whose consent must be obtained before any barrel is accepted for export.

Barrels are normally made of American oak and hold approximately 48 to 50 lb. of grapes ; they measure about 16·5 to 19·75 in.

The grapes are packed in finely ground cork, about 11 lb. being used in each barrel.

In Italy[47 67] considerable progress has been made in the methods of distribution of table grapes.

In 1917 a co-operative society was founded at Terracina in Latium, for the sale of Muscats, and at the present time about 850 out of 900 viticulturists of the district are members. Members are pledged to deliver all their grapes to the society. The society does the packing and arranges all details of transport and sale, and also fixes prices. At the store, 700 women and 50 men are employed from the end of July till the middle of October.

A daily grape train runs from 10th August to 10th October. In 1927, 988 trucks containing 7,381 tons of grapes left Terracina, of which 805 belonged to the association, and of these 561 were destined for Italian and 244 for foreign markets.

The distribution of raisins is perhaps best directed in California.

In 1910 the Californian Raisin Association of Fresno was formed. About three-quarters of the producers now belong.

The greatest attention is paid to packing and presenting an attractive product.

Notes on the present position of Production and Marketing.[66]

1. *Table Grapes.*—At present, the most important producers of fresh table grapes are Spain, Italy and France, and the most important consumers Great Britain, Germany, France, Italy, Switzerland, &c.

Briganti[8] gives a list of world exports of table grapes for 1924–25. The total amount exported was about 133,000 tons to which Spain contributed 37·4 per cent., Italy 28·01, France 20·97, Portugal 4·04, Algeria 3·71, Holland 1·97, Belgium 1·62, Rumania 1·10, Hungary 0·23, Channel Isles 0·33, Cape Province 0·45, Australia 0·17 per cent.

The British market is supplied very largely by Spain and to a lesser degree by France, Belgium and Holland, grapes being grown under glass in the last two countries.

In *Spain* grapes take the third place among agricultural products, being only surpassed by cereals and leguminous crops.

Of the produce, Spain herself consumes about three-quarters, two-thirds of the remainder going to England. The value of her total export of table grapes in 1924 was 24,622,950 pesetas or just over a million pounds.

The production in 1924 was 230,224 tons, in 1925 231,680 tons, the exports being approximately 51,000 and 44,800 tons respectively.

The most important provinces for the production are Almeria, Madrid, Badajoz, and Malaga.

In *France* most of the produce is consumed at home. In 1924, France exported about 26,450 tons of fresh grapes, of which more than two-thirds went to Germany and about

one-eighth to Switzerland and one-eighth to the Saar. Exports in 1925 and 1926 amounted to some 29,276 tons and 16,275 tons respectively.

The most important producing areas are Hérault, Vaucluse, Lot et Garonne, Tarn et Garonne, and Seine et Marne, which produced in 1922 the following amounts :—

Vaucluse	on 6,363 acres	20,282 tons (English)
Hérault	„ 7,413 „	14,172 „ „
Lot et Garonne	„ 7,660 „	10,068 „
Tarn et Garonne	„ 7,474 „	11,909 „
Seine et Marne	„ 486 „	582 „

From *Portugal.*—Exports to England in 1924–25 amounted to 1,448 and 2,276 tons respectively.[8]

Algeria.—In 1912 exports of table grapes were approximately 1,191 tons, practically all of which went to France. In 1918 this export had nearly ceased, but since that time trade has steadily revived, most of the consignments going to the French market via Marseilles. Other markets just touched are Germany, Switzerland and Holland. It is admitted, however, that Spain and Italy have so far had the greater success in supplying Germany with large-berried black grapes which stand transport well.

In *Italy* the chief growing districts are Emilia with 30 per cent. of total production, Apulia 18, Abruzzi 15·3, Venetia 12, Piedmont 8·6, Campania 8·4, Sicily 4·5 per cent.

The greatest impulse given to Italian production was the crippling of French production by the ravages of phylloxera in 1877.

In 1921 the National Congress at Naples strongly urged the growing of table in place of wine grapes.

In 1924, some 50,000 tons were produced, of which 38,000 tons were exported, and this may be taken as approximately an average.

Export is at its height in September, the chief market being in Germany (there is a special Italian grape inspection service at Munich station), Austria and Switzerland. Every effort is being made to increase the trade with England, where it is thought that Abruzzi, Zibibbo, Calabria and Baresana grapes would meet with approval.

2. *Raisins and Currants.*—The most important exporting countries of dried grapes are Greece, Turkey and the U.S.A. (California).

In *Greece* the area under vines is about 90,000 ha. (222,398 acres) and the average production about 120,000 tons of grapes.

The export of dried grapes is the third most important export of the country.

In 1923 the export of Black Corinths amounted to 107,958 tons and of Sultanas to 10,066 tons, three-quarters of the total going to England.

In *Turkey.*—About 57,000 tons of dry grapes are yearly produced. Exports are via Smyrna, the chief customers being England, the U.S.A. and Germany.

The most important raisin producing areas of *Spain* are Valentia, Alicante and Malaga.

Production in 1925 amounted to 82,242 tons, of which about one-fifth was exported.

Exports are made to England, Germany, Portugal, Venezuela and France.

California.—More than half the exports of dried grapes go to Great Britain and Canada. In 1913, the export of dried grapes to the former was just under 2 tons ; in 1922 it had risen to 170 tons, and in 1926 to close on 200 tons.

Australia.—In 1924–25, out of 24,932 tons exported, 22,917 tons went to Great Britain.

VI. SUMMARY OF PRESENT POSITION OF VINE DISEASE CONTROL.

Physiological.

Non-parasitic troubles have in many cases been aggravated by the necessity for grafting.

Their remedy may be said to lie in the proper adaptation of scion to rootstock to soil, proper soil treatment and manuring, adequate drainage and aeration, reasonable pruning and cultivation of the vines, and protection from extremes in weather, and, generally speaking, attention to environmental conditions.

The position as regards parasitic diseases is very admirably drawn by Moreau and Vinet,[54] the sense of whose article is as follows :—

The happy-go-lucky days of planting one's vine and gathering the grapes, sometimes abundant, sometimes scanty, were first threatened by oidium and mildew and were finally brought to an end by phylloxera.

A new situation then arose. Grafting as practised means a larger return but a greater leaf surface, and so more opportunity for parasitic attack. Faes is correct in considering that the action of certain parasites is favoured by (1) change of habitat of crops, (2) selection processes, wherein the equilibrium of plant growth is broken and an abnormal development of certain parts occurs, (3) specialised cultivation, (4) importations and exchange between countries. Thus *Esca*, once nearly unnoticed, has now become a serious menace.

Fungicides.

The most efficient remedies evolved as yet are copper and sulphur against oidium and mildew, arsenic and nicotine against insects.

The remedies having been found, it was later realised that the method and occasion of their employment are just as important as the substances themselves. Moreover, the futility of isolated treatment is gradually being realised.

Progress made lies in the better knowledge of the proper proportions of salts necessary for effective treatment, in the introduction of casein or gelatine as aids to adherence, and in the realisation that when failure occurs it is due, not to the inefficacy of the copper, &c., but to the fact that the times of spraying were ill-chosen, that the copper ratio was not sufficiently high, that the surface of the leaves was not properly covered, &c., &c. Attempts have been made to inform viticulturists as to proper times for treatment by the establishment of warning stations, whence warnings, (based on meteorological data, and observance of the growth of the vine and its parasites), are issued of the possible attacks of mildew. They have not been successful, largely owing to the fact that viticulturists, warned of a possibility and spraying accordingly, may often find the possibility not fulfilled. The scheme therefore fails in its chief aim, which is to obtain the maximum of protection with the minimum of treatments.

Mildew.—Insurance by early preventive spraying has become recognised as the best course.

The combination of these two early treatments with that against Cochylis and Eudemis is a successful innovation. Cupric powders have been found a useful supplement—though supplement only—of the liquid treatments. Improvements have been made in the spraying apparatus, and it has been found that when large scale apparatus is used, it is necessary that the nozzles should be directed by hand so as completely to cover the required surface.

Oidium.—Sulphur is still the accepted remedy. Polysulphides have not hitherto given such good results as sulphur, but deserve further trial.

For sulphur-shy vines permanganate of potash has been found useful.

Other practices lately recognised as extremely useful are the proper aeration of the soil, the removal of leaves at the level of the grape bunches, and the disinfection of wood with $FeSO_4$ or H_2SO_4.

Root Rot.—The maintenance of the soil in a proper state of aeration and CS_2 disinfection after contamination are now considered essential.

Esca.—Experiments have been made in recent years on the effects of winter treatment of vines with arsenite of soda. Its direct results against Esca is excellent, and in the opinion of Moreau and Vinet might well be ranked as an established remedy against many of the diseases attacking the stem. Its actual effect is unknown, though it is thought to help the flow of the sap. Moreau and Vinet are now investigating this point.

Court Noué.—This is realised to be due to a combination of circumstances ; in every case attention must be paid to soil conditions.

Plant pathologists are now beginning to grapple with the problem of the resistance or receptivity of plants to cryptogams, as also the virulence or attenuation of those diseases.

Selection has produced potatoes immune to wart disease, clovers immune to *Sclerotinia trifoliorum* and varieties of vine resistant to mildew and oidium.

Cazeaux-Cazalet and Capus have shown that the vine is not continuously susceptible to black rot, the favourable times being shown by the plant tissues, i.e. after rainy cold days when the end of the shoot is deprived of starch, and receptivity is great.

Laurent considers that, as the nutrition of the mildew fungus is dependent on osmotic conditions, which in turn depend on the concentration of liquids, the solving of questions of immunity and receptivity would involve a study of the internal milieu in the plant. Others also admit that the starch content in the tissues plays an important role.

Bottini has found, on spraying the leaves of San Gioveto and of d'Oeillade with a solution of Pinot leaves (a variety considered by him immune to mildew) and inoculating them with mildew, that, by comparison with other leaves similarly inoculated, the development of the mildew is retarded or that the number of infection areas is less.

These and other experiments lead one to have hopes of a day when it will be possible to treat plants with serums and vaccines against disease, as it is now possible to treat animals.

Insect Control.

The methods tried at various times may be classed as follows :—

(1) Suppression by capture.
(2) Suppression by mechanical or physical means.
(3) Suppression by insecticides (internal and external action).
(4) Suppression by counter parasites.

At the present time, far the most important method is that of insecticides.

Again, an essential condition, granted an efficient insecticide, is the knowledge of the insect's habits and its most vulnerable periods. Thus the effect of insecticides against the chrysalis of cochylis in its refuge under the bark is trifling, but excellent against the larvæ of pyralis.

The supremely useful insecticides in use at the moment are arsenate of lead, nicotine and pyrethrum soap, the latter being the most recently introduced.

The laboratory must never be the final test, and many remedies, excellent under laboratory conditions and even in the experimental field, have been found to fail in general practice. On this point, and dealing particularly with such a case in the treatment of Eudemis and Cochylis, the writers' opinion is as follows :—At the present time it is rather the exception to treat vines only slightly infected, and control measures are only taken in years of serious infestations, that is to say, under conditions where the efficacy of the control measures, given the reduced percentage of mortality obtained in practice, cannot always be seen in the saving of a considerable amount of the crop. We believe that control measures should be carried out every year, and above all—we should be tempted to add—in years when the attack is feeble and in vineyards little infested. Our object is the progressive reduction in the number of insects, with a view to decreasing the number and importance of the serious attacks. This can be achieved, even if the yearly mortality only reaches 50 to 60 per cent. by treating every year and in every vineyard which is in the slightest degree contaminated.

The attainment of such efficient control is only possible by co-operative effort, such as is seen in Champagne and elsewhere, which alone can ensure the three conditions of success: (*a*) methodical and accurate application of control methods previously determined by experts, (*b*) generalisation of treatment, (*c*) continuity of treatments.

Such organisation is actually seen to-day in the various " Syndicats de Défense," which may embrace a whole district, or a commune, or at least an important number of adjacent vineyards. In Algiers the establishment of such associations was responsible for the fact that in 1925 80 out of every 100 vine growers treated their vines against Eudemis.

There is a continual need for the further study of the life history of parasites, animal and vegetable, and for the perfection of their control methods, and it is to the perfection of these methods rather than towards new insecticides and fungicides that Moreau and Vinet would direct new research.

The critical periods, i.e. the periods of maximum vulnerability, both of vine and of parasite, must be studied and turned to account.

The work would be made easier by always practising the selection of scions with an eye to their disease resistance.

Treatment must be adequate and at the proper time.

The organisation of counter measures, as to-day advised by practical experts, and embracing large groups of vineyards thanks to the formation of defence syndicates, should provide the conditions essential to success, while no effort should be relaxed tending to the discovery of simpler adaptations of present methods or of new roads to security.

VII. PHYSIOLOGICAL TROUBLES.

The so-called physiological diseases of the vine embrace all maladies which owe their origin to the fact that the vine is being grown in a place or under conditions where in the natural course of events it would not grow, or at all events, would not produce grapes with any regularity.

Frost.—The Germans and others who yearly face the threat of partial or total failure of their vintage have studied the question of prevention and cure of frost from every point of view, and in Babo and Mach,[1] as in other German manuals, the subject is exhaustively treated.

The writer does not propose to discuss the question as to whether the actual destruction of tissue is due always to the effect of too rapid thawing or to the action of the frost itself, and would only stress the salient points in the defence against and the remedies after frost.

Frost is to be feared at three times of the year—autumn, winter and spring.

(1) *Autumn Frost.*—This is the least formidable. Perold describes the effect seen by himself in a vineyard of Riesling vines at Wiltingen in Germany thus :—" The leaves had nearly all dropped, the stalks of the bunches were as brittle as glass, and the berries were reddish brown. . . . They cannot produce a wine of high quality."

Other authorities such as Pacottet[61] do not consider that the wine will be affected, if the grapes are ripe at the time and are harvested at once. The following evil effects, however, may be seen—abnormal susceptibility to chlorosis in the following year, death or injury to the bearing wood of the next year due to incomplete ripening, general check to the plant owing to the fall of leaves before all their work is finished. Any previous weakening by insect attack, as was the case in the Tyrol in 1891 (attacks by red spider (*Tetranychus telarius*)) makes the possibility of any such occurrence all the more to be feared.

Apart from specific remedies, in places where such early frosts are possible, late ripening varieties should not be used and excessive nitrogenous manuring should be avoided.

(2) *Winter Frost.*—The greatest danger here is to be feared from successions of hard frosts and sudden thaws rather than from continuous hard frost. The experience in the Côte d'Or is that the effect is less if pruning is done in the spring rather than in the autumn.

In Northern Italy, in Emilia, the shoots are bent to the ground and either covered with earth or with straw in dangerous localities. In the Balkans the whole plants are earthed up against eventualities. Both here and in Germany certain losses are experienced every hard winter.

The chief advice given is to use only such varieties and strains as are known to resist well, to plant fairly deeply and to take care to keep the root and, in the case of grafting, the joint well covered.

(3) *Spring Frost.*—Frost in the spring is much the most formidable danger.

The whole year's harvest may be ruined by one severe spring frost.

Where frost occurs to any appreciable extent, viticulturists have to be on their guard. Some of the points for attention to prevent any such disaster are :—[13 14]

Varieties :—Late budding varieties are preferable.

Sites :—Hillsides are preferable to the plain, low-lying ground surrounded by hills being especially dangerous. Proximity to water tends to decrease radiation and hence minimise the risk of frost.

Ground :—To prevent radiation, this should be kept weeded, but should not be in a mulch at a time when frosts are to be feared.

Pruning :—Late is preferable to early pruning, as it is conducive to late budding. One long shoot may be left and trained high above the ground. If the lower buds are nipped, the top ones may possibly escape.

Chemical devices :—Spraying with a 40 per cent. solution of $FeSO_4$ or with a 10 per cent. solution of H_2SO_4 is advocated by Chancrin as delaying the opening of the buds by 8–10 days. Powdering the young buds with a mixture of wood ash and sulphur is also advocated by the same authority.

Irrigation :—In Hérault and elsewhere, where water is easily obtained, the vineyards are irrigated (*see* page 35) to prevent frost damage. It is not essential that the water should cover the soil, but that it should well saturate it and so lessen radiation.

Spraying with cold water :—This prevents a too rapid thaw after frost.

Shelters :—Used in Germany, Champagne and elsewhere in vineyards producing luxury wines or grapes.

Smoke clouds :—These are formed by the firing of débris, tar, &c., put in large containers at, say, 15 yards interval, around the vineyards to be protected and with one or two lines of them running through the vineyards at intervals of 50 to 100 yards from each other. The contents are lighted when the thermometer at about 8 in. from the ground is at 35·5 F., and kept burning till all danger of a too rapid thaw has passed. The purpose is to form artificial clouds which will prevent radiation and in case of necessity stop the too rapid action of the sun.

Tar is in many places by no means easily obtained and it would not appear impossible for the chemists to produce a substance[51] which would give out very heavy clouds of smoke at a low cost without damaging the vines or requiring so much attention. In any case, the possibility of the necessity of smoke clouds on any night should be advised by the meteorological office and some device must be arranged for the alarm to be given if the temperature falls to the danger point. Castella suggests that the actual heating of vineyards by braziers as in orchards in California is worth a trial.

The writer considers that certain instructions given by Babo u. Mach and an additional comment by Dr. Biermann,* may be of interest.

Thus in Babo and Mach :—

Treatment following spring frost varies according to the stage of development and to the damage done.

(*a*) *The buds frosted before bursting.*—Here a certain number of the dormant side buds will grow out. If, however, the chief buds have already been killed by winter frost, no hope is left that the side buds will be fruitful.

(*b*) *Shoots partially or totally frozen for a length of* 3–5 *centimetres* (approx. 1–2 in.).—The damaged shoots only should be all removed, this being most easily done by breaking. The same applies to the adventitious shoots. Part of the previous year's subsidiary eyes which lie at the base of the shoots so removed burst into growth and give a small return.

(*c*) *Shoots* 15–25 *cm.* (approx. 6–10 in.) *only the tips frozen, fruit buds apparently undamaged.*—Removal of frozen parts prevents further necrosis, which otherwise spreads with disastrous results. The last bud generally forms a growth which will be useful in pruning for the following year.

(*d*) *Shoots as in* (*c*) *but frozen to beneath the fruit buds.*—All shoots are removed with a sharp knife to within ½ cm. from the last year's wood.

(*e*) *Shoots* 35–60 *cm.* (approx. 14–24 in.) *tips frozen.*—No action necessary.

The aim is to keep the vine in bearing. Hence, owing to the natural weakening consequent on frost damage, all the above measures must go hand in hand with the application of fertilisers, recovery being largely proportional to the amount of plant foodstuffs in the soil.

---

* Chief Viticultural Lecturer at the "Lehr- und Forschungsanstalt für Wein- Obst- und Gartenbau." Geisenheim on Rhine, Germany.

It is recommended that the following amounts of fertiliser be given :—

40 kg. nitrate or soda, or
50 kg. sulphate of ammonia
100 kgs. superphosphate,
50 kgs. 40 per cent. K_2O salts per morgen, or approximately 1½ cwt. sulphate of ammonia, 3 cwt. supers., and 1½ cwt. 40 per cent. potash salts per acre.

Damage by frost necessitates additional after care. The better the plant food content of a vineyard and the smaller the number of new fruit-bearing shoots, the greater is the number of adventitious shoots which should be kept on the vinestock so as to provide a leaf surface corresponding with the root system.

Finally, pruning for the proper development of the vine in the following year demands particular attention. The removal of adventitious shoots and the proper choice of shoots for training necessitates the greatest possible skill and care in the year following spring frost damage.

Dr. Biermann, to whose help the writer is greatly indebted, commenting on the above writes :—

. . . In addition to the instructions given in Babo and Mach, I have found it best in the case of spring frost to remove all frost-damaged growth down to the lowest subsidiary eyes. This must be done directly after the occurrence, to avoid a great wastage of water.

If only the unburst eyes are frozen, then at the subsequent pruning a fairly long bearing wood should be left in order to retain a number of undamaged eyes on the fruiting branches, usually only a certain number of the eyes being frozen.

Manuring is essential, especially the prompt application of 40 kg. nitrate of soda or 50 kg. sulphate of ammonia ; this should be followed at a later stage of growth by 100 kg. supers. and 50 kg. 40 per cent. potash salts per morgen.*

The adventitious shoots which do break out must be treated with the greatest care and more subsidiary shoots should be left on the plants than are generally allowed at the first spring trimming, in order that they may take the place of the damaged bearer wood.

Experiments at Lausanne have led Dr. Faes[33] to consider that any trimming of vines is unnecessary when the frost has only damaged the undeveloped buds, or the young shoots or the ends of the branches, and that even when the branches are frozen as far as the fruit buds, leaving only an undamaged base, any trimming is of doubtful benefit. In his opinion adventitious buds, if still intact, or, otherwise, the dormant buds will always develop. The cold after-wind may be relied on to stop the flow of sap and remove dead growth. He also considers that one of the most important points is care in spring trimming, which must be shown in the elimination of excessive or badly placed shoots, so as properly to prepare for the following year.

In 1913, his experiments gave no proof that grafted vines resisted frost better, but those of 1925 showed most noticeably that the oldest vines were the worst affected. Grafted vines, moreover, were found to be more resistant than ungrafted older vines, while direct producers (*see* page 14) were the most resistant of all, especially Gaillard 157, Gaillard 2, Seibel 138,156, Couderc 88,51, 117,3, 146,51, Castel 1028, Noah.

Hail.—Vineyards should not be established in districts especially notorious for hail. The damage done varies according to the development of the vine and the intensity of the storm. One of the most usual effects is the breaking of the skins of the grapes with consequent entry of fungi. German authorities advise spraying with Bordeaux mixture immediately after such damage.

* As recommended by Babo u. Mach.

The utility of paragrêles and of hail cannon is very doubtful.

Where shoots are damaged, the vines must be cut back severely to prepare for the following year.

Hail insurance is the only adequate safeguard.

*Drought.**—The vine is comparatively drought resistant, but in those parts where it is successfully grown despite normal long periods of dry weather, special precautions are adopted. Thus, in Almeria, famous through the world for its table grapes, the rainfall is very small. From figures given by Briganti[27] for the period 1911–1917 the average annual rainfall is seen to be only 180·3 mm., the number of rainy days 32·7, very little rain, 6·3 mm. and 6·5 mm. respectively, falling in June and September, and none in July and August ; in these four months, the average maxima and minima temperatures were for June 79°·8 and 60°·9 F., for July 85°·7 and 67°·9, for August 87°·7 and 70°·4, and September 85° and 66°·6 F. Three irrigations each of 900–1,000 cubic metres of water per ha. are applied yearly with excellent results.

Other expedients are deep planting and deep preparation of the soil as practised in Latium and other parts of Italy. There, it is not uncommon for the ground to be thoroughly worked to a depth of $1\frac{1}{2}$ to 2 yards. (*See* page 39.)

Perold stresses the advisability of planting vines far apart under drought conditions.

A careful choice of rootstocks is essential when there is danger of drought (*see* page 28).

Sunburn.—In temperatures such as obtain in the north of Italy, Professor Marescalchi[49] is satisfied that the injuries commonly attributed to the sun or to the sun and dew drops, or to the sun and sulphur, are actually injuries caused by a previous blow followed by exposure to the sun's rays. He therefore strongly deprecates any work of any sort taking place in the vineyard at the time when the grapes are changing colour. In less fortunate climates, however, where higher temperatures are experienced or where the sirocco or other type of obnoxious hot wind blows, the danger is much greater.

While taking other common sense measures, such as precautions against drought, non-use of sulphur in dangerous weather, the avoidance of specially susceptible varieties, &c., the viticulturist is recommended to harden the grapes by removal of the bottom leaves, to keep the bunches in the shade from 12–3 p.m., if necessary running rows east and west, to train sensitive grapes high on shady pergolas and to top early so as to get strong shoots with enough laterals to give shade.

Coulure and Millerandage.†—Coulure and Millerandage, which signify respectively the falling off of the dead flower without fertilisation having taken place and imperfect fertilisation resulting in the formation of a small seedless berry, may be due to vagaries of the weather, to malnutrition connected with faults in pruning, or to malformation of the flowers. Certain varieties are more susceptible than others.

Malnutrition may consist of too great stimulation of the vegetative parts of the plants by excessive nitrogenous manuring or the vine may be pruned too short, or, on the other hand, it may be enfeebled by disease or excessive cropping and so not form its flowers properly. In these cases, the remedy is obvious.

Occasional bad weather at flowering time cannot well be guarded against, but the fact that certain varieties are more prone to this physiological phenomenon than others stresses the necessity for testing new varieties before planting on an extensive scale. Moreover the greatest care must be taken in selecting scions for grafting or planting out.

---

* *See also* page 27.

† *See also* notes on ring barking, etc.

Certain individual Gamay plants, for instance, are very prone to millerandage in dry soils, but it has been found in the Côte d'Or[32] that its incidence can be avoided by strict attention to proper nutrition, maintenance of proper soil conditions, choice of rootstock and choice of scion from plants which are never found to show millerandage.

Generally speaking, the remedy lies with the grower.

Chlorosis.—Chlorosis (*see also* page 26) or the yellowing of the leaves which, if allowed to continue, will eventually result in the death of the vine showing these symptoms, is a nutritional disease, the most usual ultimate cause being the presence in the soil of excessive amounts of soluble $CaCO_3$.

Certain varieties show greater resistance than others, but Cettolini stresses the fact that the resistance of these varieties, such as Berlandieri, will vary, not only in accordance with the quantity, but also with the solubility and state of division of the lime, and further with the amount of water in the soil.

In addition, Houdaille and Semichon have in their experiments shown the tremendous part played by the state of soil saturation and have found that where this amounts to 50 per cent., chlorosis is bound to occur in the presence of much or little lime, finely divided or not.

American vines are especially susceptible. Thus Chancrin[20] found that Riparia Gloire du Montpellier throve in a soil containing 10–15 per cent., but died in one containing over 20 per cent. $CaCO_3$. European vines on their own roots do not suffer to the same extent. Being a nutritional disease, it naturally occurs with more effect when the plant has been weakened in any way, such as by phylloxera on the roots, &c., and, similarly, it is much more to be feared in grafted American vines than in those not grafted. There the affinity factor makes itself felt besides the susceptibility of the scion and of the rootstock. Its effects on slightly susceptible grafted stock are found to be worse when the grafting is done on the spot than in the case of a bench graft planted out.

In any lime-rich soil, the viticulturist will be wise to get his soil tested before planting up with any new varieties hitherto untried in that district, and for this purpose Cettolini agrees with Perold in recommending the use both of an ordinary calcimeter such as the de Asti, Bernard, &c., and a special calcimeter, e.g. the Houdaille, which determines the rate at which the lime dissolves in a 25 per cent. solution of tartaric acid.

Wherever it is possible, moreover, official tests of chlorosis resistant stocks and scions should be made and the results published. Many lists have been made of varieties of American stocks which will resist the presence of different degrees of lime.

When disease occurs, the remedy lies in supplying the necessary foodstuffs available, e.g. by drainage and adding potash ; or in the neutralisation of the effect of the $CaCO_3$ by the application of very large amounts of iron sulphate, either in crystal form or in solution to the soil, or in spray form on the chlorotic foliage using a 1 per cent. solution ; in avoiding the use of physiologically alkaline fertilisers such as nitrate of soda ; and, if replanting has to be undertaken, in planting chlorosis resistant varieties, which can stand the soil conditions. And herein lies the secret of its prevention. In Perold's words, " the safest procedure is first to lay out experimental plots with different stocks and different scion varieties and to apply the experience gained in selecting the stock."

A practical experiment was seen by the writer in Richter's vineyards at Montpellier, where in one field of very calcareous soil (by analysis 60 per cent. of active $CaCO_3$) Aramon was being tested on various rootstocks.

The whole field of about 4 acres or more had been planted in 1925 with rooted stocks of different lime-resistant varieties, which had then been grafted with Aramon the

following spring. The differences in growth were very marked. Thus 161–49 (Riparia × Berlandieri Couderc) has given complete success and abundant fruit as from the second season ; 150–15 (Berl. × Aramon Rupestris Ganzin de Malègue) has been nearly a total failure. Between these two extremes 41-B, 1202 and especially R 31 have given excellent results.

M. Faucherre* judging from his own experiences, thinks that had all the grafting been done at the bench, the results would have been much more level.

Court Noué or *Roncet.*—Pantanelli[62] still remains the chief authority on this mysterious disease. He considers that its symptoms are due to a poison originating in not properly decomposed organic material in the soil, though Petri's[64] experiments in Sicily have led him to attribute it there to the effects of winter cold. Petri found in the vines already affected " cordoni endocellulari " (or thin rods) inside the cells, which would at least serve to identify the disease.

Certain varieties of both rootstock and scion are notoriously subject to the disease, e.g. Rupestris du Lot. Its occurrence can be largely obviated by planting in properly aerated soil where vines have not been grown for a year or two. Cettolini suggests that when a case occurs it is advisable to remove the diseased vine and expose the soil in which its roots have lain to sun and frost.

Two interesting experiments in France of attempts to remedy outbreaks are reported by Soursac[81] in 1927.

Occurrence.—Case 1. Soil argillaceous, calcareous ; vine Carignan grafted on 3309, aged about 15 years, trained goblet fashion : the 1,500 plants affected are in a depression in the midst of an otherwise healthy vineyard of 8,000 plants. The first growth was normal, but an excessive number of secondary adventitious growths was noticeable, the leaves being puffy and distorted. Flower formation was good but fertilisation bad, and coulure occurred on nearly all the grapes directly after their formation. There had been a steady decrease in yield during the past eight years despite the ordinary removal of the young shoots as on the healthy vines.

Remedy: In 1927 at the time of flowering, the owner removed all the secondary branches.

Result: As a result, the Court Noué was checked on the shoots freed from the secondary growth, the coulure was stopped and a normal crop obtained.

Case 2. Soil siliceous, argillaceous ; vine Carignan on Riparia Gloire de Montpellier, aged about 26, trained goblet fashion. The vines which are in a depression of the vineyard had shown signs of Court Noué for 5–8 years, and were each year giving smaller yields, that of 1926 amounting to less than one-third that of the unaffected vines.

Remedy: In the winter of 1926–27, at the last winter pruning, on a certain number of plants in the affected area, only one arm was left and on this arm two long bearers of 1·25 m. in length. On each of these bearers the bottom eye was left to act as bearer wood at the next pruning, the two adjoining eyes were suppressed, the fourth left, Nos. 5 and 6 were suppressed, the seventh left, and so on, six to eight eyes in all being left. Each plant thus had twelve to fourteen eyes, i.e. the usual number in goblet training. These long bearers were trained vertically.

Result: Court Noué was checked and the growth of adventitious shoots, &c., was practically nil. The crop was even better than that on unaffected vines.

---

* Faucherre, R. Administrateur-Délégué of the Société anonyme des Pépinières Richter.

Soursac explains these results as follows :—The diversion of sap to the adventitious shoots in 1926 and in preceding years had caused coulure, as often occurs when too much vegetative growth is made. The removal of these parasitic organs allowed the grapes to benefit by the proper supply of food. In the first case, the expected adventitious shoots were prevented from appearing, while in the second the vertical position of the attached long bearers checked their development.

The actual increase over the unaffected grapes reported in the second case, was due to (1) the use of the eyes in the centre of the shoot, those so situated being normally the most fertile ; (2) the raising of the shoots from above soil level where they are often damaged by the grey *Agrotis* larva, in which case the less fertile side bud carries on ; (3) the less sheltered position of the branches with resultant diminished effect of eudemis and cochylis.

Soursac does not hazard any prophesies as to the permanent effect of such treatment, which really amounts to a temporary readjustment of the food supplies, but he stresses the fact that both cases occurred in depressions in the vineyard and strongly urges that the greatest care should be taken to get rid of any such hollows by levelling before planting.

Cettolini stresses the fact that the disease is aggravated by bad adaptability of rootstock to ground, by faults in pruning, by excessive cutting, by exhaustion in old age, by planting in soil formerly under vines and not afterwards worked or rested enough, now by one now another factor.

The same authority in the *Giornale vinicolo italiano* of 6th November, 1927, mentions cases of the failure of vines in Sicily, where the surprised vinegrower has applied for advice, the vine having perished after showing many of the symptoms at present grouped under Court Noué.

In many cases Cettolini has found that such dying off has resulted from :—(1) too deep burying of the graft junction and consequent rotting ; (2) a misguided attempt to save time in cases of European vines dying from phylloxera on the part of the grower, who, without any attempt to work the ground, plants American cuttings close to the diseased vines. When the European vines finally expire, they are pulled up and the American cuttings, now rooted, are layered over to the exact place of the old dead vines. Thus the grower gets two new vines in place of one old dead one. These two are grafted, but the sanguine and preposterous hopes of the grower are not fulfilled. In a year or two, he sends in a complaint with regard to the American stock supplied. The stock is scarcely to be blamed, but the damage is done.

Rougeau.—Of other non-parasitic diseases of the vine probably the Red Disease, Rougeau[74] or Rougeot[73], has attracted the most attention of late years. The characteristic feature of the disease, from which its name is derived, is the premature reddening of the leaves and stem, which is often accompanied by Court Noué symptoms and by coulure.

In 1927 its occurrence was very much more serious than usual in France.

Ravaz reports its presence this year on isolated plants among healthy ones and in isolated groups in particular portions of the vineyards. The first attack may come on a plant showing excellent young growth, with the result that the shoots borne in spring become stunted, and may either only ripen very slightly at the base or remain quite unripe ; the foliage is more or less red ; the disease is not contagious. Naturally the plants attacked develop badly in the following year. Sometimes in the first year only one branch will suffer. Coulure is evident and the grapes do not develop normally.

Ravaz notes that it has been especially noticeable on vines grafted on Riparia and on 3309, those on Jacques remaining healthy, while of the scions Aramon seems particularly susceptible.

He suggests that the following circumstances tend to favour the spread of the disease :—deep planting, roots all leaving at the same point—as is at present the case in the rooted stocks formed from some part or other of American cuttings—and consequently undue pressure exerted on one another ; vine branches all leaving at the same spot ; an irregular swelling of the stock near the joint resulting in partial or total encircling of the stem close to the joint with consequent pressure, as, for instance, in the case of 3309, Riparia, &c. ; the unequal growth of rootstock and scion, where the former, not able to keep pace with the latter, prevents its growth by pressure—a fact, indeed, which is not without value for fruiting purposes ; everything which tends to cause obstruction in any way and give the effect of ring barking—such obstructions are not usually found on Jacques and other rootstocks giving regular and excellent joints ; and sometimes perhaps in sandy soils lack of aeration round the deep penetrating roots.

In the cases that came to his notice lately, he suggests as palliatives elementary draining between the rows and regrafting with scions other than Aramon. In addition, without guaranteeing success, he recommends the use of manures containing straw for the aeration of the soil, possibly with the addition of some calcium fertilizer having an oxidifying effect, such as nitrate of lime.

It should be noted that abnormal red coloration is also brought about by the fungus *Pseudopeziza tracheiphila.* (Müller Thurgau, *see* ch. ix.)

Brunissure.—Brunissure is a minor physiological disease somewhat troublesome in Algeria and elsewhere. It is not as yet reported in South Africa or in Italy. Perold, quoting Ravaz, notes among other points :—(1) It is not parasitic ; (2) it is the result of overproduction ; (3) it is a disease of young vines.

Apoplexy.—This may be physiological or due to a Basidiomycete fungus, *Stereum necator* Viala (Esca).

The plant, or part of it, wilts suddenly and does not recover. Ottavi and Strucchi have noted its frequent occurrence in Italy in the summer following a too deep working of the soil in spring, where the roots have been damaged by an implement, or after hot spring winds. It is also experienced when hot weather follows a cool rainy period.

When due to *Stereum necator* or "Esca"[84]—whose name is due to the tinder like appearance of the heart of the affected shoots—treatment with alkaline arsenites is recommended by the leading authorities.[19 7] Viala points out that Esca does not attack vines till about their fifteenth year or later, after which, on signs of the disease, he suggests treatment for two successive years followed by a year's rest, and then repetition as before. This should suffice. Treatment must be repeated as it does not kill all the germs, some of which merely remain dormant and on the absorption or removal of the destructive element revive.

A very serious attack of Esca occurred in 1927 in Spain, where in Socuellamos, one the most important viticultural districts, the crop was reduced by more than a half. Hitherto its occurrence had been on isolated vines and little trouble had been taken with it.

This fungus is certainly one whose coming should be most carefully noted and investigated.

Other non-parasitic diseases.—From time to time new forms of non-parasitic disease[38] are noted, which are difficult to label as rougeau, chlorosis, &c., and at first it is thought that some old parasitic disease has broken out in new form. Any such disease is, however, usually found to originate in malnutrition or overproduction.

Such are the California or Anaheim disease, and various diseases investigated in Tunis, France and elsewhere.

VIII. DISEASES OF THE VINE—INSECTS.

*Phylloxera vastatrix**.

Certain modern authorities, such as Topi, of Siena, are still studying this disease, chiefly in so far as concerns its different biological races. Börner has distinguished two biological races only, one of which, the pervastatrix form, has been found in Germany. He points out, therefore, that by only using stock such as Rip. Gloire, Rip. × Rup. 3306–3309, &c., &c., on which this pervastatrix race cannot propagate itself, phylloxera will in course of time die out there.

Its life in all its forms, whether sexual, winged, root or leaf, has been very thoroughly investigated and needs no comment here.

According to Topi,[83] its chief methods of spreading are (1) the movement of rooted cuttings, grafted or ungrafted, during the hibernating season ; (2) any sort of carrying agent, boots, earth, leaves, stakes, &c., &c., leaving an infected vineyard during the active period of the insect's life, the insect being attracted up to the surface of the soil by the light, and then being transported by any one of a thousand agencies.

Control measures.—(1) *Extinction* by means of bisulphide of carbon. This destroys the vines as well. (2) *Cure*, which must be repeated as it does not exterminate the insect. CS_2 is again the ordinary agent, potassium sulpho-carbonate also being used. This attempt at a cure was practised in Austria-Hungary up till the war, and even now it is legally subsidised in Italy.

The only other known method is that of submersion. This has been practised and is still practised in certain districts of Southern France. It is not usually possible, and when practised it must take place yearly, owing to the survival of some of the eggs. The vines remain submerged between 21–40 days and afterwards need considerable manuring to make up for the salts leached out.

A fact which may occasionally be turned to use is that phylloxera cannot exist in sand, possibly because in sand the water manages to occupy all the interstices between the particles, possibly because the insects cannot move about so well, and sometimes because, as in volcanic sand at Etna, the temperature induces in the root-forms a sort of aestivation (or dormant summer period) at a time when normally the insect would be most active.

The author saw large areas in the neighbourhood of Aigues Mortes, Hérault, devoted to Aramon vines, ungrafted, growing in the sand. These flourished and showed no signs of phylloxera.

(3) *Restrictions on movement of vines or parts of vines.*—Such restrictions are maintained with the greatest of difficulty. A more feasible regulation is the disinfection of parts from

* *See also* Chap. II, "Reconstruction difficulties in Italy."

infected areas. The following methods have been found effective :—(1) Immersion in water at a temperature not rising above 132° F. nor falling below 125·6° for 5 minutes. This needs very careful operators, and is usually beyond the power of small nurseries. (2) Immersion for 30 minutes in a 0·2 per cent. solution of sodium cyanide. This is a dangerous substance and the solution is liable to chemical change, which prevents the efficacy of the treatment. (3) Faes and Staehelin (quoted from Topi) found that immersion for 12 hours in potassium sulpho-carbonate 3 per cent. solution, containing 1 per cent. of black soap is successful. The length of the process is against it. (4) The common disinfection against scale insects of citrus fruits and other plant parasites, i.e. exposure to HCN fumes for one hour.

The leaf form has been occasionally found to attack the leaves of American mother vines so virulently as to reduce considerably the wood produced and actually affect the health of the plants. In this case, Balbiani's mixture[87] brushed on at the end of winter has been found effective.

Balbiani's mixture	Heavy oil of tar, 20 parts,
	Naphthaline, 60 parts,
	Quicklime, 120 parts,
	Water, 400 parts.

In Italy, in cases of such attacks becoming serious, recourse has sometimes been had to this process, but generally, labour being cheap, it has been found just as efficaceous to send squads of children round to pick the infested leaves while very young.

Moreover, the practice adopted in some countries of covering the head of the vine with soil may sometimes prevent the laying of the winter egg.

All the above measures, however, in the present state of our knowledge are mere makeshifts to postpone the evil day. Sooner or later, in normal soils phylloxera will take possession, and every step should be taken to reconstruct vineyards before its coming (*see* page 16 and subsequent pages).

Cochylis and Eudemis[85]. *Clysia ambiguella and Polychrosis botrana.*

Cochylis (*Clysia ambiguella*) and Eudemis (*Polychrosis botrana*) are, after phylloxera, the most important insect enemies of the vine to-day in European vineyards. In Switzerland control treatment is now compulsory, and in France and Germany the liveliest interest is taken in their control.

Although differing somewhat in appearance and number of generations, their effects and their control treatment are much the same.

Eudemis seems, for reasons unknown, to be gradually displacing cochylis in Europe. Very briefly, the damage is done by the eating of the blossoms by the first generation, the spinning together of the dried shrivelled blossoms and the prevention of fruit formation. The larvæ then pupate in the flower or grape bunches or in the leaves. The moth emerges when the grapes are filling and lays her eggs on the berries, stalks, &c. These hatch and the caterpillars penetrate the grapes; the latter are spoilt and the juice exudes, forming an excellent culture medium for grey rot (*Botrytis cinerea*). Sometimes the damage caused by this fungus much exceeds that done directly by the insects themselves.

The actual times of hatching, &c., vary with different climates. The following estimate is given by Dr. Stellwaag[82] for Germany. In a warmer climate, the dates would be earlier and the processes somewhat accelerated.

(a) Cochylis.

I Generation :	Egg laying	12–15 days	6–7 weeks—end of May to mid-August.
	Caterpillars	25 ,,	
	Pupas	10 ,,	
II Generation :	Egg laying	10 ,,	Mid-August till April.
	Caterpillars	20–25 ,,	
	Pupas	8–9 months	

(b) Eudemis.

I Generation :	Egg laying	5½ days	4–5 weeks (early May to early June).
	Caterpillars	22–28 ,,	
	Pupas	5–6 ,,	
II Generation :	Egg laying	4–5 ,,	About 4 weeks (mid-July till mid-August).
	Caterpillars	21 ,,	
	Pupas	5 ,,	
III Generation :	Egg laying	5–6 ,,	8–9 months (early September till April).
	Caterpillars	22–28 ,,	
	Pupas	7–8 months	

The larvæ of the last generation normally pupate under the bark or in the crevices of old stakes.

Control Measures.

Winter Treatment.—Various treatments have been suggested and tried with varying success. Among them are :—

(1) Removal of old bark after previous spraying with hot, acid iron sulphate. For ordinary commercial vineyards this is not an economic proposition.

(2) Boiling water treatment. Soda is added to the water to help penetration.

(3) Suffocation with sulphur dioxide.

(4) The use of pyralifuges in the form of alkaline arsenites such as are used against the " Esca " fungus. Though this treatment is not considered economical purely against eudemis and cochylis, it has, when used against Esca, a most salutary effect on the incidence of attacks by these insects.

Summer Treatment.—Destruction of the caterpillars or moths themselves. The time of any such treatment must depend on the observation of the flight of the moths and a calculation of the appearance of the caterpillars from the eggs then laid.

The use of lamps surrounded by water attracts the insects to their death, but is said to have the disadvantage of actually attracting insects from one part of the vineyard to another and so increasing the areas infested by the following generation.

Food traps baited with wine lees, water and vinegar placed on the ground in various parts of the vineyard at a distance of about 20 yards from each other also form an excellent method of noting the progress of the infestation.

The moths flying in the dusk or early morning are so caught and counted. Treatment should start against the first generation caterpillars about two days after the total catch has begun to recede from the maximum, and for the second and third also when the numbers begin to decrease.

This treatment may under certain conditions of cheap labour merely consist in the employment of squads of children and women, &c., whose duty it is to go through the vineyards inspecting every vine and squashing or removing every caterpillar seen. The writer was informed by Prof. Briganti of Portici as also at Avellino that this method in itself has been found most successful in southern Italy.

The alternative is spraying. Spraying must be done with some substance poisonous to the caterpillar. Such substances as lead arsenate, copper arsenate, or lime arsenate, are, in the order given, the most efficacious. Various pyrethrum, nicotine and phenol preparations may also be used, the first, however, being at present too expensive for general use.

In France the use of arsenical preparations after the time of flowering is forbidden, although a most energetic and reasoned protest against this ruling is made by Viala and Marsais.* Experiments by Muttelet, Bouligaud and Kohn-Abrest, Faes and others, lead Viala and Marsais to the opinion that wine is in no way endangered by the treatment of the vines with arsenates, even arsenate of lead, up to the veraison period, i.e. the time when the grapes begin to change colour, and that authorisation for their treatment could well be given, if not for a later period, at least after flowering.

At the same time they own that after flowering treatment with other substances such as pyrethrum, &c., can, although less effective, prove a sufficient remedy.

It has luckily been found that the treatment, especially of eudemis, which would be an added and costly expense, can well be combined for the main part with the treatments against Oidium and Downy Mildew (*Plasmopara viticola* Berlese) : Dr. Stellwaag of Neustadt strongly advocates this. Accordingly, Viala and Marsais recommend, after long and successful experiments, that the following shall take place :—" Three treatments shall be given of arsenical copper solution sprays against the first generation, the first when the branches are 15–20 cm. long, the third at the end of the flowering and the second in between these extremes, while a powdering with sulphur impregnated with nicotine shall be given in between the second and third of these treatments.

Against the later generations : treatment with copper solution, to which nicotine or pyrethrum has been added, shall be made at the moment when the baited trap check shows that the number of moths is decreasing, this treatment to be completed by two or three powderings with sulphur impregnated with nicotine at regular intervals after the spraying up to the time of harvesting, the last not later than ten days before this. Where labour is cheap, removal of the leaves above the bunches is advisable. This method has been found absolutely adequate in southern France and has been successfully adopted."

Solutions.—Viala and Marsais, add arsenate (preferably of lead) to the copper solution, rendered somewhat alkaline, in the following proportions :—1 kg. lead arsenate to 2 kg. copper sulphate to 1 hectolitre of water or approx. 1 lb. to 2 lb. to 10 gallons.

Nicotine is added to copper solutions (rendered strongly alkaline to help the liberation of the alkaloid). The amounts used are 133 gm. of pure nicotine per hectolitre (very roughly 2 oz. per 10 gallons), or 1·33 litres of 10 per cent. nicotine solution, or 0·26 litres of 50 per cent. solution. The addition of various phenol compounds to the copper has also been found to answer well.

The usual precautions must be taken when arsenic spraying, the Germans advocating the use of special masks.

Perold notes that all varieties of grapes are not equally damaged by cochylis, and that various other plants such as lilac and ivy act as hosts of the insect.

Professor Silvestri[80] of Portici gives a list of 26 insect parasites of eudemis. So far, however, it has not been found possible to control it by the use of any such natural enemies.

---

* i.e. for Wine grapes only. Moreau and Vinet have shown that its use after flowering is dangerous in the case of table grapes, *see* bibliography No. 54. *See also* footnote on page 59.

MM. Retournat and Pheline, owners of vineyards at Oued-et-Alleug, report in the *Revue de Viticulture,* 13th October, 1927, that, being in a district badly ravaged by eudemis, their vines which are grown in alternate rows with tobacco have been quite free from this plague.

That prevention has so been achieved would appear to be proved by the fact that slight attacks of eudemis have actually occurred in the same vineyards on the edges where is no tobacco.

The question arises whether the moths have found their flight physically impeded by the high tobacco plants or whether growing tobacco has a specific value. The question would appear one worth following up, not merely as regards eudemis treatment but in any place where tobacco growing is favoured and where vines become infested with insect pests on which nicotine, at least in its concentrated state, has a salutary effect.

Recent Trials in Champagne.—The A.V.C. or Association Viticole Champenoise, which is one of the most powerful and efficient viticultural bodies in France, has in 1927 continued and intensified its cochylis control measures.

Its Director, M. Chappaz[21], has reported to the viticultural section of the " Société nationale d'encouragement à l'Agriculture " on this year's operations, from which a few of the salient points are as follows :—

Treatment was carried out in 1927 on an area of about 2,000 hectares (or 4,942 acres).

Over this area only 3 or 4 per cent. of the vine growers proved unwilling to co-operate.

The amount and cost of the chemicals supplied through the A.V.C. for use on this area were :—

Approx. 669·2 cwt. Swift's arsenate of lead (costing 230,000 fr.).
Approx. 153·5 cwt. American nicotine (costing 470,000 fr.).
Approx. 74·8 cwt. French nicotine (costing 230,000 fr.).

Printed instructions were sent out as to the necessary precautions in handling and using the insecticides, as to the preparation of the solutions and the time of treatment.

A comparison of 1926 and 1927 shows that the first generation moths were more numerous in the latter year and that their flight lasted 15 days in 1927 as against 10 in 1926. The second generation on the other hand except at one place, where no treatment had been given, was much less numerous than in the preceding year, a fact showing the effectiveness of the treatment. Two treatments were advised against each generation, the first with arsenate, the second with nicotine. In addition, powderings with nicotine-impregnated sulphur were also carried out in some cases.

The removal of the leaves above the bunches, advised as part of the control of the second generation gave excellent results.

The arsenate was mixed with the anti-mildew copper solution which in no way suffered in efficacy. The first treatment was found effective on pyralis, while the action of the arsenate on the cigarier insect (*Rhynchites betuleti*) was very noticeable.

No difficulty was found in mixing the arsenate of lead, which was in paste form, with the copper solution. Adhesion-inducing substances were added, but no soap. The nicotine was delivered at a strength of 500 gr. per litre or approx. 50 lb. per 10 gallons.

The treatment of the second generation was directed specially up on to the grapes from below.

Various types of small and large spraying apparatus were used. The necessary improvements in these is to form the object of special study. Despite the storms and constant rain showers throughout the season, treatment was extremely successful.

Conclusions reached by Chappaz.—The counting of larvæ after treatment with arsenic is not a very reliable test of its effectiveness, as the arsenic acts slowly and does not necessarily kill at once.

In nearly every case, the result of treatment has meant a tremendous increase in return compared with that obtained on control plots, often being very much more than double.

Arsenates are greatly preferred to nicotine, being much cheaper, much less objectionable to use and providing a much more lasting effect, a fact which is of the utmost importance when the period of flight and egg-laying is greatly prolonged as happened in the second generation of 1927.

The only possible contingency which may prevent treatment in 1928 is lack of funds.

Observation made in 1927 suggest certain desirable modifications such as the use of three arsenical mixed treatments against the first generation and a varying number of nicotine treatments against the second, *unless the use of arsenates is sanctioned after flowering.** [53]†

The writer of this report has gone into considerable detail over these two pests, which apparently do not occur in South Africa or Australia,‡ partly because of their supreme importance in Europe and partly as illustrating the method of control adopted.

Pyralis. *Oenophthira pilleriana* (*Tortrix pilleriana*, Schiff).

This pest has of late been somewhat overshadowed by cochylis and eudemis, but is, nevertheless, capable of doing very serious damage.

Perold reports that neither it, cochylis nor eudemis are as yet known at the Cape.

The caterpillars can be controlled in the summer by the same methods as those used against cochylis and eudemis.

The insect differs chiefly in its habits from the above in that it only possesses one generation a year and hibernates in the crevices of the bark as a caterpillar, protected by a silky web, to emerge in the spring and envelop the leaves and tendrils on which it feeds and pupates. From the chrysalis a moth emerges about mid-July and lays fifty to sixty eggs. These hatch, and the circle is complete. It has many other host plants.

The number of control methods advised by different authorities is very great. The following would appear the most important :—

(1) Gathering leaves on which are the quite visible eggs. This treatment must be repeated.

(2) Fumigation with sulphur dioxide in winter. This is only possible when the vines are trained low and can be covered.

(3) Hot water treatment before the buds burst.

(4) Removal of old bark by means of a metal glove.

(5) Collection of leaves containing pupæ.

(6) Spraying with lead arsenate in the spring after the emergence of the larvæ from hibernation.

---

* Chappaz' italics.

† By Decree of 15th February, 1928, the use of certain arsenical substances is authorised in vineyards up to the time of veraison or change of colour.

‡ *See Bulletin No.* 50 (*new series*) of the Dept. of Agriculture of Victoria on Oidium (1924) by Castella and Brittlebank on page 33, footnote :—" Eudemis, cochylis and pyrale are tortrix caterpillars responsible for an enormous amount of damage in French vineyards. Seeing that they are rather closely related to our Australian light brown apple moth, the danger of this last becoming a disastrous pest in Australia seems very real."

Vivarelli[87] strongly recommends treating the vine and the stakes in winter with Laborde's mixture. This is—

For vines :		For stakes :	
Quicklime ..	30 parts, by weight.	Heavy oil ..	10 kg.
Heavy oil ..	10 ,,	Oleic acid ..	2 kg.
Caustic soda ..	1 ,,	Caustic soda ..	0·5 kg.
Sulphide of carbon	5 ,,	Water	90 litres.
Water	54 ,,		

Excellent results have also recently been obtained by Dalmasso and Consolani by the use of a new arsenate of lime summer spray called, "Azol" made by the "Società del Caffaro" of Milan.

Luckily the insect possesses many virulent parasites such as species of *Xanthandrus*, *Ichneumon*, *Agripon*, *Pimpla*, *Limneria*, *Monodontomerus* and others.

Altise. *Altica ampelophaga.*

The Altise is a small hopping insect, blue-green above, black below, which occasionally proves very troublesome in Spain, France and Algeria. The perfect insect winters under heaps of dead leaves, old bark, &c. In the spring, it lays eggs on the under surface of the leaves and these hatch after seven to eight days. The black larvæ spread over and eat the young buds, shoots, leaves and inflorescences. After about a month, the larvæ fall to the ground, where in the soil they become first nymphs and about four weeks later, in July, adults. Several generations may occur in a year.

It has sometimes proved serious in Bas Medoc,[45] where vineyards close to pine woods have been severely attacked.

Control methods include[28] (1) knocking the adult insects off the vines into a bagged, fan-shaped receptable, or a pan containing a shallow layer of kerosene ; (2) the preparation of shelters beneath the vine in autumn of old loppings, &c., in which the insects will gather for collection later ; (3) arsenical spray treatment and the sending of poultry among the vines.

Scale Insects.

Whilst never yet occasioning any such disastrous results as their close relation phylloxera, scale insects do from time to time cause serious damage in vineyards.

A few of the points from Grassé's article on the subject[39] may be of interest :

Numerous requests for information show that various scale insects, notably *Icerya purchasi* aided by favourable climatic conditions, are spreading.

Many kinds are found on the vine, but only a few as yet have done serious damage to it.

A list of nineteen, which is not considered complete, is given of such insects. The following are definitely ampelophagous : *Targionia* (*Aspidiotus*) *vitis*, Sign, *Eulecanium persicae*, Fabr., *Pulvinaria vitis*, L., *Pseudococcus* (*Dactylopius*) *vitis*, Niedel, *Rhizoecus falcifer*, Künck.

Targionia vitis has never been known to do serious damage to vines.

Damage due to *Eulecanium persicae* has, however, been more serious.

Although unknown by Grassé to exist in Africa or South America, its range is very great. In France it is very widespread, rather wet districts such as the Médoc apparently favouring its development.

In France the eggs are laid in May and June and hatch out almost immediately, the larvæ proceeding on to the leaves. Development is slow, and it is not until October that

the larva sheds its skin and migrates to the shoots to pass the winter there in full activity. The following spring, it grows very quickly, undergoing a second morphological change about April.

The most serious damage is done at this period ; the vine is punctured and sweet sap is exuded in which sooty mould very frequently develops. The insect, moreover, inoculates the plant with a poisonous juice affecting the tissues. Trees so affected may be seen retaining their diseased leaves beyond the normal time.

By adhering to the old wood, it can continue its existence undisturbed by pruning, and serious damage may in this case be done by the bleeding and poisoning process.

It also attacks wistaria, rose, plum, pear, peach and mulberry trees.

Control treatment advised is spraying at the end of winter with the following mixture :—

Quicklime	40 lb.
Heavy oil	10 lb.
Water	15 gallons.

The slaked lime is powdered and the heavy oil added with vigorous stirring. When well mixed, the whole is diluted to 15 gallons.

It may be sprayed or applied with a brush.

The insect has numerous parasites which prey on it.

Pulvinaria vitis is now identified as another form of *Pulvinaria betulae.*

It is not now so dangerous as in the days of long pruning.

It may be suppressed by squashing the females which remain after pruning at the base of the shoots, or by removal of the dead bark, or by the latter operation followed by spraying as detailed above.

Pseudococcus vitis : the female of this scale carries on each side of her body 17 waxy projections which enable her to be distinguished from *P. adonidium* and *citri*, a very similar scale. It is exclusive to the vine.

It has several generations each year : in France, usually two ; in Northern Africa, three or four.

It can live on every part of the vine including the grape.

It comes from the Near East, where it is widespread in Palestine and Syria, as also in Tunis, Algeria, Rhodes and most of the islands of Greece and in Italy.

In Palestine those insects which live underground in association with a saprophytic fungus (*Bornetina corium*) produce a curious affection known as " Jaffa disease " which has been studied by Mangin and Viala. The roots pierced by the insect exude sap which, moistening the soil, allows the spores of *B. corium* to germinate. A stroma of mycelium is formed round the root, imprisoning the scales. The roots so enveloped die, as does the vine at the end of three or four years.

To the treatments mentioned above may be added disinfection of the soil by the injection of bi-sulphide of carbon or the interring close to (but never touching) the roots of 10 to 20 grammes of the crystals of paradichlorobenzine.

A scale insect from Australia, *Cryptolaemus Montrouzieri,* which feeds entirely on other scales, preys on the eggs, larvæ and adult. This counter parasite has been successfully introduced and acclimatised in the French Maritime Alps, and the same process is taking place satisfactorily in Algeria.

Rhizoecus falcifer causes considerable damage to the vines in Sicily, forming small, cotton-like masses on the roots. In Algeria vines planted where palm trees have previously stood are often infested.

Generally speaking, its effects have not been serious.

Perold mentions the increasing damage done by the Mealy bug (*Pseudococcus capensis*, Brain).

The white bugs are seen crawling from berry to berry when the grapes are about to turn colour.

Perold, speaking from personal experience, notes that its most serious appearance is on grapes forming big compact bunches.

Mally's method of control is by means of hydrocyanic gas released under gastight tarpaulins. This kills both the insects and their eggs.

Perold states that they may be killed, if seen early enough, with water at 158° F. This treatment needs repeating.

He also quotes C. K. Brain as suggesting the trial of spraying with 4 per cent. Clensel.

Root-Eelworms or Nematodes. *Heterodera radicicola*, Greef.

These eelworms have been found to do damage to vines at the Cape, in Portugal and in Italy.

Perold notes that sandy soils suffer most from them. Cettolini has noted them on ill-drained soils, rich in organic matter.

The remedy appears to lie in good drainage and the use of suitable rootstocks.

Erinosis.[64] *Eriophyes* (*Phytoptus*) *vitis* (Land.), Nal.

This insect which attacks the leaves is very widespread, but ordinarily causes little damage.

The writer noted in his tour many instances of its occurrence, but it was not considered of importance.

In bad cases, sulphuring has been found efficacious at the Cape.

The Mediterranean Fruit Fly.[64] *Ceratitis capitata*, Wied.

This insect attacks the fruit of late varieties.

The writer has been unable to find any reference to damage caused by this fly to vines except in Perold's Treatise.

In 1915, 90 per cent. of the Almeria grape crop at the Paarl Viticultural Experiment Station was so destroyed.

Perold recommends the use of Mally's "Fruit-fly bait," namely, 3 lb. brown sugar, 3 oz. lead arsenate (50 per cent. paste), 4 gallons water, as a safe and sure control.

Calandra.[64] *Phlyctinus callosus*, Bohem.

This insect is a beetle indigenous to the Cape, having one generation per year.

It is not exclusive to the vine and is worst in clay and peaty soils.

It eats leaves, shoots and grape bunches, especially the last, often going from grape to grape and spoiling them for dessert purposes.

It feeds at night, living in the day time under clods of earth, old bark, &c.

Control methods.—Perold recommends arsenate spraying (3 lb. lead arsenate to 50 gallons water) up to, but not later than, the time when the berries are $\frac{1}{25}$ of an inch in diameter.

The beetles may also be prevented from climbing on to the vine by some tangle-foot arrangement.

Collection of specially prepared débris in which the beetle will lurk during the day has also proved useful.

The Grape Root Worm.[40 41] *Fidia viticida.*

The larva of this beetle has been the most serious pest of vineyards in the Chautauqua and Erie regions of New York and Pennsylvania.

The adults are greyish brown, about ¼ in. long.

They appear on the leaves at midsummer and are active there for about two weeks. After mating, the eggs are laid in late summer under the loose bark of the entire vine with the exception of the roots. Some two weeks later cream coloured bugs about ·04 in. hatch out, fall to the ground, and burrow down to the roots on which they feed. In October in N.Y. county they burrow down to a depth of 1 ft. or more, returning the following May close to the surface to pupate about four to eight inches below it. The first beetles emerge about the last week in June.

The leaf damage is usually negligible, but that on the roots may kill the vine and will certainly greatly decrease its vitality and yield.

They are preyed on by Carabid beetles.

Extensive experiments have led to the following control methods being recommended :—

(1) Spraying with molasses (1 gallon), lead arsenate (6 lb.) and water (100 gallons), followed in about a week by the application of Bordeaux mixture (8–8–100) plus arsenate of lead (6 lb.).

(2) Two applications of Bordeaux mixture (8–8–100) plus arsenate of lead (6 lb.), at an interval of about ten days.

The first system of treatment is recommended when the beetles are present in very large numbers. The second, for general vineyard spraying when they are not so abundant.

There are in addition innumerable pests of which no account can here be given. Each country has more than its own fair share.

The writer is led by his meetings with vinegrowers and viticultural experts and by perusal of existing literature on the subject to consider that the most serious insect pests of European vineyards to-day are phylloxera, eudemis and cochylis, the importance of the rest varying very greatly.

IX. DISEASES OF THE VINE. FUNGI.

Oidium. *Uncinula necator* (Schwein), Burr.

This disease is very fully dealt with by Perold for South Africa, and by Castella and Brittlebank for Australia.[17]

No great advance would appear to have been made in its treatment in Europe.

The most generally accepted treatment would still seem to be sulphuring, the fineness being more important than the purity of the sulphur.

In cases where frequent rain prevents the sulphur from operating, the application of soft soap (half per cent. solution) along with the Bordeaux mixture used against mildew is recommended by Zillig[90] ; the latter stresses the fact that sulphur in powder form is much the best remedy.

In Italy[19], the first powdering very frequently takes the form of a mixture of 40 to 50 per cent. sulphur with powdered quicklime or sifted ash, 50–40 per cent. plus 10 per cent. copper sulphate or " Caffaro " powder, a powder made by the " Società elettrica ed elettrochimica del Caffaro " at Milan.

The Bombay Department of Agriculture, Leaflet No. 6, of 1927, stresses the necessity for repeating the sulphuring when rain removes the sulphur before three or four days sunshine has induced its action on the fungus, for covering the whole of the exposed surface of the vine, and for the treatment of every vine.

Downy Mildew. *Plasmopara viticola.*

This is fully dealt with by Perold and by Castella and Brittlebank.[16] European practice[72] agrees with that recommended in South Africa and Australia.

Experiments[52 56] are made yearly by the chief stations and viticultural associations in Europe in the hope of finding improved control methods. 1927, an admirable year for the purpose, has at least shown which remedies are not efficient. Thus, attempts to substitute part of the copper sulphate, bringing its quota to below 2 per cent., by lime sulphate proved futile. Colloidal mercury solution was also found useless.

Similarly cupric powders have been tried in vain in comparison with Bordeaux mixture, giving the same number of applications in both cases ; they are useful, however, as a supplement to Bordeaux treatment.

Experiments on the whole have tended to show that adequate protection can only be given by keeping the leaf well covered with copper solution, despite the constant removal of the latter by rain, during the time when the fungus is dangerous. This is best done by spraying, as necessary, with slightly alkaline Bordeaux mixture, which should contain at least 2 per cent. of copper sulphate, i.e. at least 2 lb. copper sulphate per 10 gallons of water.

It has been found that the addition of arsenate to the early cupric solutions, as mentioned in the account given of the control of cochylis and eudemis, allows these two diseases to be controlled at the same time as mildew.

Faes and others agree as to the desirability of adding casein or skimmed milk to aid adherence.

Cadoret,[11] Director of Agriculture in the French province of Savoy, has for many years since the disastrous year of 1915 strongly advocated what he calls " La vigne bleue " or blue vine.

Shortly, his aim is to keep the vine covered with a strong basic solution which appears very blue from a distance during the whole of the dangerous period, i.e. for about six to seven weeks in Savoy.

His mixture is copper sulphate 2·5 to 3 lb., lime 2·5 to 3 lb., water 10 gallons.

Two consecutive treatments of this should be made in the first fortnight of the danger period, two in the second fortnight, and one at the end of the period. After this, he recommends spraying with a mixture of the following ingredients : Copper sulphate 1 lb., lime 2 lb., water 10 gallons, as required.

His results have undoubtedly been excellent, and in trials in Champagne in 1927, made in Moet and Chandon's vineyards by Moreau, the vines so treated gave the best yield. This result, however, was nearly equalled by that following the application of alkaline Bordeaux mixture containing not less than 2 lb. of copper sulphate per 10 gallons water. The latter cost less, and was very nearly as effective.

It was found in the above experiment at Epernay that the keeping of the Bordeaux mixture for one, two, three or four days, had no effect whatever on its efficacy.

Anthracnose or Black Spot.[15] *Gloeosporium ampelophagum* (Pass.), Sacc.

This old European disease, which is most to be feared by the grower of table grapes, is effectively kept in check by preventive winter treatment with iron sulphate and sulphuric acid.

No innovation has occurred in the method of its treatment of late years and the incidence of its appearance in Europe has not been very serious.

Black Rot: *Guignardia Bidwellii* (Ell.), Viala and Ravaz.

This disease may be controlled by the same Bordeaux mixture as is used against mildew, only, the treatment must start earlier, i.e. when the young shoots are about 8 cm. long, and apart from intermediate spraying, Perold recommends a thorough spraying about two months after blossoming.

Grey Rot. *Botrytis cinerea.*

This parasite of the grape is of the greatest importance, chiefly under its name of the "noble rot," being largely responsible in normally dry seasons for the exquisite aromatic flavour of the sweet Sauterne, the "vini passiti" or sweet dessert wines of Italy and of some of the Rhine wines, and, to a smaller extent, in very wet seasons, for a serious and objectionable rotting of the grape attacked.

When it occurs in its first form it is welcome and the grapes are collected separately.

It becomes serious, as in 1927, when after bad attacks of cochylis and eudemis the fungus, aided by wet weather, completes the ruin started by the grape worms. The writer saw considerable evidence of this at Conegliano, Dijon and elsewhere.

Various remedies are proposed by various authorities, but often with a note added that none have been found entirely satisfactory.

Its incidence is important only in abnormally wet seasons.

Root Rot. *Rosellinia necatrix* (R. Hart), Berl.

The writer has been unable to trace any new research work on this fungus.

The last word at present would appear to have been said by Perold—in agreement with other authorities—"The only effective remedy is effective drainage."

Perold advises removal of sick vines for 6 to 9 ft. around the spot affected, the growing of cereals for two or three years, the deep working of the soil and its injection with $1\frac{1}{3}$ oz. per square yard of CS_2 for two years.

Rougeau.[55] *Pseudopeziza tracheiphila* (Müller-Thurgau).

This fungus causing discoloured patches on the leaves of vines is dependent for existence on faulty environmental conditions.

It can be checked by spraying with Bordeaux mixture, but according to Zillig and Niemer[91], being essentially due to environment, its treatment should vary accordingly and should consist of—(1) the addition of humus-forming material on hot dry, hillsides; (2) the proper working of the soil on light crust-forming soils which do not warm up well in spring.

White Rot. *Charrinia diplodiella,* Viala and Ravaz.

This fungus, first noticed more or less simultaneously by Cettolini and Cataneo in Italy, is not of great importance as yet, and may be controlled according to Cettolini by the same treatment as mildew, and according to de Istvanffi (quoted from Babo-Mach) by spraying with a $2\frac{1}{2}$ per cent. solution of potassium metabisulphite and sulphurous acid and a 3 per cent. solution of magnesium sulphite, which quickly kills the spores.

Dead Arm Disease. *Cryptosporella viticola.*

L. C. Coleman[26] describes this as the most serious vine disease in Ontario. It is present in all the important grape growing areas of the province, where an infection of 11–50 per cent. of susceptible varieties is found.

The symptoms are—(1) death of vines or arms ; (2) stunting of growth in leaf-bearing branches and leaves, with deformation and chlorosis of the latter ; (3) stem and arm lesions associated with old pruning wounds.

The chlorotic symptoms do not disappear later. Infection is by means of the conidial fructifications or pycnidia, which are emitted from May to September through the pruning wounds.

Control measures are—(1) marking in June the affected parts below the lowest stem lesion and removal thereof at the pruning season ; (2) spraying in May the pruning wounds once or twice to prevent spore infection.

Considerable information is given in Coleman's article and in other works referred to by him.

Bacterial Diseases.

These have been little studied.

The " Rogna della vita,"[18] which has been induced artificially by inoculating healthy vines with *Bacillus ampelopsorae*, Trevisan, is as yet the most important. All bacterial diseases of the vine flourish under bad soil conditions.

SUMMARY.

The differences which may be noted in good viticultural practice in different regions are generally due to variations in soil, climate and object in view.

Direct action control of phylloxera has now been relinquished in favour of indirect action, namely, grafting on phylloxera-resistant rootstocks.

The efforts of geneticists, which were originally directed towards the discovery of varieties which would be resistant to phylloxera and retain this resistance when vegetatively reproduced, now tend rather towards the obtaining of hybrids which are not necessarily phylloxera-resistant, but which show great resistance to physiological, insect and fungus diseases.

The utmost importance attaches to the proper adaptation of rootstock to soil and of scion to rootstock.

Care in selection of scion and rootstock is essential. Pure vegetative varieties of both can be obtained and official action would appear desirable to prevent the spread of inferior and misnamed varieties.

Only prolonged trial in each locality can prove the suitability of any particular rootstock for that locality.

Attempts to improve clonal varieties by selection of cuttings based exclusively on yield records of the parent plants are doomed to failure.

Certain physiological effects of grafting on rootstocks and on scions are noticeable.

The incidence of physiological disease is more serious among grafted vines.

The influence of the rootstock on the quantity and quality of wine is considerable, but is not apparently so great as that of other factors, such as season and soil.

Calculations as to what manuring is necessary must be based on considerations of meteorological and soil conditions and the aim of the grower.

The effect of manures is found to vary greatly according to the form in which the particular foodstuffs are given.

Certain cultural practices are especially to be recommended when the object is the production of table grapes and raisins.

Considerable stimulus has been given to the production of table grapes in Spain by the help of the government, and in Italy and California by the combined action of the viticulturists.

The importance of unrelaxed, organised control measures against insect pests even in quiet years is now realised.

Hitherto the most successful insect control measures have been the use of sprays containing some form of insecticide, such as arsenic, nicotine or pyrethrum.

Research on the best methods of fungi control is now being directed towards the discovery of the most vulnerable periods in the life of the fungus and of the vine and to the application of this knowledge.

The possibility at some future date of breeding immune varieties which will yield adequate crops of good quality, and of conferring immunity by means of serum injections is no longer negligible.

REFERENCES.

1. *Babo und Mach.*—Handbuch des Weinbaues, Zweiter Halbband, Vierte Auflage. Paul Parey, Berlin, 1924.
2. *Biermann, Prof.*—Der Stand der Versuchspflanzungen und die Versuchsergebnisse mit veredelten Reben an der höheren staatlichen Lehranstalt für Wein Obst und Gartenbau zu Geisenheim a Rh. Die Deutsche Wein-Zeitung, Mainz.
3. *Bioletti, Frederick, T.*—Vine pruning in California, parts I and II. University of California publications, Bulletins 241 and 246, University of California Press, Berkeley, 1914.
4. *Bioletti, Frederick T.*—Selection of planting stock for vineyards. Hilgardia, Vol. 2, No. 1. Berkeley, California, July, 1926.
5. *Blunno, M.*—The use of phylloxera—resistant stock. Department of Agriculture of New South Wales, Farmers' Bulletin, No. 80, Sydney, 1914.
6. *Bonnet, L. O.*—New facts about girdling. In the California Fruit Grower, Vol. 6, No. 4. San Francisco, April, 1925.
7. *Bonnet, L. O.*—A promising remedy for black measles of the vine. University of California, Circular No. 303, Berkeley, February, 1926.
8. *Briganti, G.*—L'uva da tavola all' estero. In L'Italia Agricola, Piacenza, August, 1927.
9. *Briganti, G.*—Le uve passe. Piacenza, 1927.
10. *Briganti, G.*—Alcuni aspetti dell' agricoltura spagnuola : *see* Dalmasso.
11. *Cadoret, A.*—La vigne bleue. Comptes rendus des séances de l'Académie d'Agriculture de France, Tome 7ème, No. 38, Paris, December, 1921.
12. *Carpentieri, F.*—Delle cause che influiscono sulla maturazione dell'uva e sulla composizione dei vini. Libreria dello Stato, Rome, 1924.
13. *Castella, F. de.*—Spring Frosts. In the Journal of the Department of Agriculture of New South Wales, September, 1920.
14. *Castella, F. de.*—Repruning of vines damaged by frost, hail, &c.—Ibidem, October, 1919.
15. *Castella, F. de and Brittlebank, C. C.*—Anthracnose. Department of Agriculture of Victoria, Bulletin No. 42, Melbourne, 1918.
16. *Castella, F. de and Brittlebank, C. C.*—Downy mildew of the vine. Department of Agriculture of Victoria, Bulletin No. 49, Melbourne, 1924.
17. *Castella, F. de and Brittlebank, C. C.*—Oidium of the vine. Department of Agriculture of Victoria, Bulletin No. 50, Melbourne, 1924.
18. *Cavazza, D.*—Viticoltura. Unione tip-editrice-Torinese, Turin, 1923.
19. *Cettolini, S.*—Trattato di viticoltura moderna, terza edizione. Battiato, Catania, 1927.
20. *Chancrin, E.*—Viticulture moderne, huitième edition. Hachette, Paris.
21. *Chappaz, G. and Bonnet, P.*—La Lutte contre la cochylis en Champagne en 1927. Imprimérie Sparnacienne, Epernay, 1928.
22. *Charmeux, F.*—Les divers procédés de conservation des raisins de table. In the Comptes rendus du premier congrès commercial du raisin de table, Agen, 1925.
23. *Chauvigné, A.*—Étude sur la résistance des hybrides producteurs directs aux maladies cryptogamiques en 1927. In the Revue de Viticulture, Tome LXVII, No. 1743, Paris, November 24, 1927.
24. *Chauzit, B.*—Forme sous laquelle la vigne semble préférer les éléments nutritifs qui lui sont nécessaires. In Le progrès agricole et viticole, No. 50, Montpellier, 11 December, 1927.
25. *Christie, A. W. and Barnard, L. C.*—The principles and practice of sun-drying fruit. University of California, Bulletin No. 388, Berkeley, May, 1925.
26. *Coleman, L. C.*—The dead arm disease of grapes in Ontario. In Scientific Agriculture, Vol. VIII, No. 5, Ottawa, January, 1928.
27. *Dalmasso, G.*—La viticoltura in Cirenaica. Imprimeria del Governo, Bengasi, 1925.
28. *Dalmasso, G., and Consolani, G.*—Un brillante successo nella lotta contro le tignuole dell'uva. Treviso, 1924.

29. *Daniel, L.*—La question phylloxérique, le greffage et la crise viticole. Gounouilhon, Bordeaux, 1908–1911.
30. *Dotti, F.*—La viticoltura e l'enologia nell'Agro Lughese. Società tipo-editrice Ravennate e mutilati, Ravenna, 1927.
31. *Durand, E.*—Manuel de viticulture pratique, troisième edition. Librairies Baillière et Fils, Paris, 1927.
32. *Durand, E., and Guicherd, J.*—Culture de la vigne en Côte d'Or. Felix Rey, Dijon, 1905.
33. *Faes, H.*—Gelées d'avril. In L'annuaire agricole de la Suisse, Lucerne, 1921.
34. *Faes, H. and Porchet, F.*—Étude de l'influence de divers porte-greffes sur la qualité et quantité de récolte, lère série, 1911–1913, IIème série, 1914–1919, Lausanne, 1914 and 1920.
35. *Faes, H., Tonduz, P. and Piguet, G.*—Étude de l'influence, &c., IIIème série, 1920–1924, Lausanne, 1925.
36. *Faes, H., Tonduz, P. and Piguet, G.*—Observations sur les producteurs-directs dans le vignoble vaudois. 111ème série, 1920–1924, Lausanne, 1925.
37. *Ferraris, E.*—La produzione e la coltivazione delle viti americane resistenti alla filossera. Istituto editoriale scientifico, Milan, 1923.
38. *Gladwin, F. E.*—A non-parasitic malady of the vine. New York Agricultural Experiment Station. Bulletin No. 449, Geneva, New York, 1918.
39. *Grassé, P. P.*—Les cochenilles de la vigne. In Le progrès agricole et viticole, No. 49, Montpellier, 4 December, 1927.
40. *Hartzell, F. Z.*—Experiments for the control of the grape root-worm. New York Experiment Station, Bulletin 453, Geneva, N.Y., December, 1918.
41. *Hartzell, F. Z.*—Dusting and spraying to control grape root-worm. New York Experiment Station, Bulletin 519, Geneva, N.Y., July, 1924.
42. *Hedrick, U. P.*—Manual of American Grape Growing. The Macmillan Co., New York, 1919.
43. *Laffer, H. E.*—The pruning of the vine. Department of Agriculture of New South Wales, Farmers' Bulletin No. 140, Sydney, July, 1921.
44. *Leonardi, F. de.*—La produzione ed il commercio delle viti americane e la legge 26 Settembre, 1920, No. 1363. Marescalchi, Casalmonferrato, 1927.
45. *Liquard, E.*—Chateau Livran. Imprimèrie Departmentale de L'Oise, Beauvais, 1923.
46. *Longo, A.*—I sistemi di potatura. In L'Italia Agricola, anno 64, No. 8, Piacenza, August, 1927.
47. *Loubet, M.*—La situation actuelle de la culture et du commerce des raisins de table en Italie et en Espagne.—Report presented to the Congrès de Viticulture de Montpellier, Montpellier, June, 1927.
48. *Manaresi, A.*—La decortazione anulare sulle uve da tavola. Societa tipografica già compositori, Bologna, 1910.
49. *Marescalchi, A.*—Esperienze ed osservazioni viticole ed enologiche. Marescalchi, Casalmonferrato, 1926.
50. *Marsaut, J.*—Culture de la vigne et vinification en Bourgogne, le domaine de Corton-Grancey. Beauvais.
51. *Meiszner, R.*—Katechismus des Weinbaues. Eugen Wimer, Stuttgart, 1927.
52. *Moreau, E.*—Compte-rendu des différents essais effectués en 1927. Moët et Chandon Service des vignes, Epernay, 1927.
53. *Moreau, L. and Vinet, E.*—Note sur l'arseniate de plomb en viticulture et la consommation des raisins frais et des raisins secs. Gauthier Villars, Paris, 1910.
54. *Moreau, L. and Vinet, E.*—Innovations dans la lutte contre les parasites de la vigne. In the Revue de Viticulture, Tome LXVII, No. 1739, Paris, October, 1927.
55. *Müller Thurgau.*—Der rote Brenner des Weinstocks (quoted from Perold).
56. *Müller Thurgau.*—Bericht der Schweizerischen Versuchsanstalt für Obst Wein und Gartenbau in Wädenswil für die Jahre 1921–1923. Verbandsdruckerei A–G, Berne, 1924.
57. *Musci, G.*—Per la coltivazione delle uve da tavola nel Mezzogiorno. Paper presented at the National Congress of Horticulture, Massalombarda, Italy, September, 1927.
58. *Musci, G.*—1 problemi tecnici della nuova Viticoltura pugliese. V. Ferri, Rome, 1922.
59. *Oberlin.*—La reconstitution du vignoble sans greffage. (Translation into French by Pierre Larue) Librairie agricole de la maison rustique, Paris, 1914.

60. *Ottavi, O. and Strucchi, A.*—Viticoltura, ottava edizione rinnovata dal Dr. W. Tammaro. Hoepli, Milan, 1921.
61. *Pacottet, P.*—Viticulture, quatrième edition. Baillière et Fils, Paris, 1921.
62. *Pantanelli, E.*—Roncet. In La viticoltura moderna, anno XVII, Nos. 10 and 11, 1911.
63. *Paulsen, F. and Maggioni, N.*—Influenza del porta-innesto e di altri fattori su la qualità dei vini. Guiseppi di Giorgi, Palermo, 1915.
64. *Perold, A. I.*—A Treatise on Viticulture. Macmillan and Co., London, 1927.
65. *Petri, L.*—Ricerche sulle cause dei deperimenti delle viti in Sicilia. Regia Stazione di patologia vegetale, Rome, 1912.
66. *Poher, M. E.*—Production et commerce du raisin de table dans le monde. Report presented at the Premier Congrès Commercial du raisin de table, Agen, August, 1925.
67. *Prosperi, V.*—Per la coltura delle uve da tavola nell' Agro Romano. In the Nuovi annali dell' Agricoltura, Rome, 1926.
68. *Prosperi, V.*—Le migliori varietà. In L'Italia agricola. Piacenza, August, 1927.
69. *Ravat, J. F.*—Les hybrides producteurs directs en 1927. In the Revue de Viticulture, Tome LXVII, No. 1743, Paris, November, 1927.
70. *Ravaz, L.*—Amélioration des procédés culturaux. Report presented at the Premier Congrès Commercial du raisin de table, Agen, August, 1925.
71. *Ravaz, L.*—Note sur recherches sur l'influence spécifique réciproque du sujet et du greffon chez la vigne. Gauthier Villars, Paris, 1910.
72. *Ravaz, L.*—Recherches sur le mildiou. Coulet, Montpellier, 1918.
73. *Ravaz, L. and Roos, L.*—Le rougeot de la vigne. Serre et Roumégous, Montpellier, 1905.
74. *Ravaz, L. and Verge, G.*—Le rougeau. Coulet, Montpellier, 1924.
75. *Ravaz, L. and Verge, G.*—Sur l'influence des éléments fertilisants sur la santé de la vigne. Roumégous et Déhan. Montpellier, 1925.
76. *Rives, L.*—Les hybrides producteurs directs dans l'Aude en 1927. In Le progrès agricole et viticole, Nos. 51 and subsequent nos., Montpellier, December, 1927.
77. *Ross, J. C. and van Niekerk, S. W.*—The manuring of vineyards. In the Journal of the Department of Agriculture of the Union of South Africa, Pretoria, January and February, 1921.
78. *Rouart, E. and Rives, L.*—Les hybrides producteurs directs. Paris, 1918.
79. *Sannino, F. A.*—La precocità di maturazione ed il valore intrinsico dell'uva. In the Rivista di Ampelografia, anno 7, No. 8, Alba, August, 1927.
80. *Silvestri, Prof.*—Contribuzione alla conoscenza degli Insetti dannosi e dei loro simbionti, III La tignoletta dell'uva . . . Boll. Lab. Zool. ed Entom. Agraria, Vol. VI, Portici, 1912.
81. *Soursac, L.*—Observations sur le Court Noué de la vigne. In Le progrès agricole et viticole. No. 50, Montpellier, December, 1927.
82. *Stellwaag, F.*—Der Heu- und Sauerwurm. Biologische Reichsanstalt für Land- und Forstwirtschaft, Flugblatt Nr. 49, Vierte auflage, Berlin, 1927.
83. *Topi, M.*—La filossera della vite. G. B. Paravia e Co., Turin, 1926.
84. *Viala, P.*—Esca, forming Nos. 1 and 2 of the Annales des Epiphyties. Institut des recherches agronomiques, Paris, 1926.
85. *Viala, P. and Marsais, P.*—Les traitements contre les vers de la grappe, Eudemis et Cochylis. In the Revue de Viticulture, Paris, 1927.
86. *Viala, P. and Pacottet, P.*—Notes et recherches sur l'influence du greffage. Revue de Viticulture, Paris, 1912.
87. *Vivarelli, L.*—Insetti nocivi alla vite, seconda edizione. Fratelli Ottavi, Casalmonferrato, 1924.
88. *Winkler, A. J.*—Some responses of vitis vinifera to pruning. Hilgardia, Vol. I, No. 20, Berkeley, California, June, 1926.
89. *Winkler, A. J.*—Some factors influencing the rooting of vine cuttings. Hilgardia, Vol. 2, No. 8, Berkeley, California, January, 1927.
90. *Zillig, H.*—Der echte Mehltau des Weinstocks und seine Bekämpfung. Biologische Reichsanstalt für Land- und Forstwirtschaft, Flugblatt 55, Berlin, 1926.
91. *Zillig, H. and Niemer, L.*—Der Rote Brenner der Reben. Biologische Reichsanstalt für Land- und Forstwirtschaft, Flugblatt Nr. 87, Berlin, May, 1927.

E.M.B. 12.

REPORT ON INSECT INFESTATION OF DRIED FRUIT

By

J. G. Myers, Sc.D., M.Sc., F.E.S.,

Imperial Bureau of Entomology

Great Britain SUBMITTED TO
THE EMPIRE MARKETING BOARD
AND
THE COMMONWEALTH COUNCIL OF
SCIENTIFIC AND INDUSTRIAL RESEARCH

NOVEMBER, 1928

LONDON:

PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE

To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller.

1928.

Price 1*s*. 0*d*. Net.

70–221–12.

CONTENTS.

(33859) Wt. P1346/460/857 500 11/28 Harrow G.3 T.S.5578

PREFACE.

Dr. Myers' report, which follows, deals with his investigation of the insect problem affecting Australian dried fruits during the season 1926–1927. Because of the pressure of his work in the Imperial Bureau of Entomology during the winter 1927–1928, Dr Myers found that he was unable to continue the investigation and in the following spring the Entomology Department of the Imperial College of Science and Technology agreed to take over the work at the request of the Imperial Bureau of Entomology. It is for that reason that Dr. Myers' report closes with the results of the investigation obtained up to June, 1927, but it should be stated that after that date Dr. Myers gave valuable advice and assistance to the Imperial College when it was taking over the work, and in particular that his report proved a most useful basis for the continued and extended investigation.

The work done by the Imperial College so far has, indeed, been concerned mainly with the examination of experimental fruit consignments arranged for either by Dr. Myers himself, or by the Commonwealth Council for Scientific and Industrial Research, as a result of his work in Australia. The results of the work done by the Imperial College are confirmatory of Dr. Myers' findings, namely that the infestation of Australian and other dried fruits, including Smyrna and Greek fruits, sometimes occurs in the London docks and warehouses ; that, at present, the Plumbridge system of fumigation is the only one generally applicable ; and that better hygiene at the landing ports and centralisation of dried fruit storage afford the best means of reducing serious delays in marketing and very considerable expenses incurred in sterilising and re-conditioning consignments infested after their arrival in this country. It must be admitted that during the past season certain parcels of Australian dried fruits have still arrived in an infested condition but, none the less, the problem of re-infestation at the home ports is a vital problem requiring organised and systematic study by all the parties concerned.

At present, the Imperial College is working in co-operation with the Empire Marketing Board both on the scientific problem underlying infestation and on the practical problems presented by the conditions prevailing in the London docks and warehouses. Dr. Myers' report forms the basis of that work and is a model of what a preliminary survey ought to be.

WALTER ELLIOT,

Chairman of Research Grants Committee.

Empire Marketing Board,

November, 1928.

(33859) A 2

I. INTRODUCTION.

THE aims of the investigation were to view entomologically the passage of the Australian dried fruit from the vine to the overseas consumer, to discover which were the most important insect pests, to ascertain at what stages in the process the chief infestation occurred and to establish on this data some means of control.

During part of August and September, 1926, the Plumbridge system of fumigation was tested and the opportunity taken to study storage conditions in London warehouses. Most of the following February, March and April were spent in Australia, chiefly in the Murray River settlements, where growing, drying and packing were investigated. Finally nearly 500 tons of dried fruit were carried on the R.M.S. " Orama," for observation on the voyage to London.

The observations apply chiefly to dried grape fruits because they are by far the most important and because cut fruits other than pears were packed before the present enquiry in Australia began. Unless otherwise stated " dried fruit " or even " fruit " in this report means " dried grape fruits " only.

The time proved insufficient either to work out the complete life history of any of the principal insects concerned, or to visit all the grape-growing centres. Conditions in the non-irrigated districts of Western Australia are essentially different from those prevailing in the irrigated areas of the east; but only half a day on the outward, and a similar period on the return journey were available for their examination. The report concerns chiefly therefore the Murray Settlements, which were adjudged the most important since only 1,500 tons are exported from Western Australia.

Without the very enthusiastic co-operation received on every hand, it would have been impossible to have accomplished as much in the very limited time available. Detailed acknowledgment of the help received would be almost impossible; but there must be especially mentioned the Commonwealth Council for Scientific and Industrial Research and its Secretary and Entomologist, the Fruit Inspection Service of the Commonwealth, the Dried Fruits Export Control Board, the executive of the A.D.F.A., and finally a very great number of the growers and packers and their Melbourne and Adelaide representatives. The assistance of Mr. A. V. Lyon, Manager of the Merbein Research Farm, was especially constant and indispensable. Unusual facilities were granted by the Sydney, Melbourne and London Authorities of the Orient Line and by the Captain and Officers of the R.M.S. " Orama " for the stowage and examination of the dried fruit carried on that ship. Finally, the help and criticism of members of the Australian Dried Fruit Board in London has been invaluable.

I have tried to keep this report as short and as immediately practical as possible; consequently a quantity of data, especially on the parasites of dried fruit pests, of more strictly entomological interest, has been reserved for publication in the appropriate journals.

J. G. MYERS,

London,

September, 1928.

II. INSECTS CONCERNED AND THEIR LIFE HISTORY.

1. GENERAL.

The chief insects infesting Australian dried fruits are the Indian meal-moth (*Plodia interpunctella* Hübn.), the saw-toothed grain-beetle (*Silvanus surinamensis* Linn.), the fig-moth (*Ephestia cautella* Walk.) and the flour-beetle (*Tribolium castaneum* Hbst.). These four are arranged according to my estimate of their relative importance. *Plodia* is responsible for the greater part of the infestation, especially of export fruit, while the attacks of the two beetles, as of several others less plentiful, are probably very largely secondary. Control measures may be directed chiefly against *Plodia* since its elimination would involve that of the others.

As in a dead tree in the forest, so in dried fruit, there is a definite cycle of insect attack. Before drying is complete the fruit attracts *Carpophilus* and *Drosophila*, and as soon as the shed is reached, or even sometimes before, *Ephestia* begins to lay eggs on it. Fruit which has been packed and stored a little while is most attractive to *Plodia*, and after a considerably longer period to *Silvanus*. It thus by no means follows that the older the fruit the more likely it is to be infested by *Plodia*.

2. *PLODIA INTERPUNCTELLA* HÜBN.

The problem of "life" in Australian dried fruit is then, for all practical purposes, concerned chiefly with infestation by the so-called "grubs" or "maggots," really caterpillars, of this nearly cosmopolitan moth.

Plodia lives with equal facility on a number of other dried food products, such as split peas, lentils, pea-nuts, nuts and various meals, and is at times a common household insect.

The eggs, which are somewhat elliptical, white and smooth or slightly frosted and easily visible to the naked eye, are deposited usually singly on or near the fruit, to the number of 200 to 400. When accessible, the actual berries are usually preferred, but many eggs are laid on the containers, on the paper linings and on surrounding objects. It is important to note that they are rather securely fastened to the substratum, or inserted into folds in the skin of the fruit.

Of the three main types of dried fruits sultanas seem to be preferred the most, and currants more than lexias. Two experiments were arranged to discover whether there was a preference for sultanas dipped, previous to drying, by any one of the chief usual methods. The nature of the dip influences very strongly the quality of the final product especially in so far as colour is used as a criterion. The amber colour so strongly favoured by the London market is obtained most surely by the cold dip, which contains olive oil. The larger of the two experiments, which confirmed the smaller, gave the following counts of eggs deposited on the three samples :—

Boiling caustic dip	66 eggs.
Modified or "temperature" dip	88 eggs.
Cold dip	185 eggs.

This experiment, combined with observations made while counting eggs, seems to show that the ovipositing female *Plodia* prefers fruit which by our own standards is the best. Thus dried-up berries with no "body" and sticky fruit are alike avoided. The

moisture content most favourable to the development of *Plodia*, as of most dried fruit insects is about 18 per cent. (Christie and Woodworth, 1923) which happens to be the average in bulk stored dried fruit. *Ephestia*, as we shall show later, prefers a drier medium, though it will attack half-dried fruit in drier surroundings.

The period of incubation of the eggs varies greatly, and much detailed work has been carried out by Mr. G. F. Hill, entomologist to the Council for Scientific and Industrial Research, to ascertain the controlling factors. Of these there can be no doubt that temperature is the most important. As a general rule, the warmer the weather the quicker the development of all stages of the moth. Eggs hatched in periods ranging from one to eighteen days, at temperature varying from 59° F. to 99° F. There is ordinarily considerable infertility among eggs of *Plodia*, in one of my experiments as much as 14 per cent. Infertility augments as the temperature rises above about 95° F. (Hill) ; but experiments on this point are rendered inconclusive by the very great individual variation. The term " infertility " is used here in a somewhat loose sense to mean non-hatching by whatever caused.

This individual variation is seen at its best in the larvae, where it almost completely swamps all other factors influencing the rate of development. It is thus possible to find larvae of the same age, living on the same fruit under the same conditions, varying in length from 2·1 millimetres to 12 or full size. This extraordinary disparity appears under all conditions and is probably ascribable to the semi-domestication which the insect has undergone.

Under these circumstances the subsequent periods of the life-history are even more variable than that of incubation, while the total cycle may vary from 31 days during the hottest part of summer (Mr. Hill's lowest record—lower by four days than the lowest Californian one) to many months if winter intervene.

Parker (1915) at Sacramento, California, found the various periods of the life-history in summer to be as follows :—

Egg 6 days ; larva 35 ; pupa or chrysalis 12 ; and adult moth 14 ;

Lovett (1921), in the cooler climate of Oregon, established the following figures :—

Eggs 4 to 8 days ; larva 60 ; pupa 10 to 20 :

Eggs hatched in an English August in 9 to 11 days. We have already seen that the shortest hatching period under Australian summer conditions was one day. As regards the later stages, which my short stay in Australia did not permit me to follow through, Mr. A. V. Lyon has placed at my disposal some interesting data from the Mildura district, best expressed in tabular form :—

	Eggs laid.	First egg hatched.	Pupated.	Moth emerged.
i.	24 January	28 January	4 September	17 October
ii.	17 October	22 October	—	3 December
iii.	17 October	22 October	—	20 December
iv.	10 to 14 November	14 November	—	19 January
v.	14 January	—	—	15 March

The larva or caterpillar is pale creamy or pinkish, with a shining brownish head, and is quite immaculate—a feature distinguishing it from that of *Ephestia*. It actually eats the fruit, beginning by gnawing the skin, but it does greater damage by soiling it with its moist and abundant faeces tangled up with silken webbing.

When fully fed it tends to leave the fruit, and even the box when possible, and to spin its cocoon in the corner of a box, in the folds of lining paper or in any convenient dark crevice outside the box. Cocoons do, however, occur at times among the fruit itself. After a variable period the larva changes inside this cocoon to an inactive pupa, from which eventually emerges the moth.

The moth is greyish, strongly marked with dark brown, the latter half of the folded wings being much darker and sharply differentiated from the rest. It is mainly nocturnal in its activities, but is especially attracted to dark corners and partially covered boxes, where it may be active at times even during the day. Outdoors, however, it ventures but little, and the main agency of spreading must be undoubtedly the distribution of already infested foodstuffs. A striking instance of its confinement to limited quarters was provided by the Mildura Co-operative packing shed, where, in early March, *Ephestia* moths were more plentiful than *Plodia* by at least 3 to 1. A small fumigating shed, kept open, and having its door five yards from that of the main shed, contained infested boxes of the previous season's lexias. *Plodia* moths were very plentiful, but only one *Ephestia* could be found. If there were much spreading in either direction this discrepancy would surely have tended to disappear, since the attraction—in the form of fruit—was present in both buildings.

The winter is passed in the larval stage, changing in late winter or early spring to the pupal state.

It is highly unfortunate that a whole year was not available, in order that the number of broods under Australian conditions could be ascertained. From the available evidence there could hardly be more than two. It seems certain that no eggs laid on dried grape fruits during the packing season will produce moths until the following spring while kept in Australia. All reports agree in stating that " moths " are most abundant in packing sheds during the first half of the summer. Some old traps examined in February contained almost solely *Plodia*, so that these reports, when based on catches inside the sheds probably refer chiefly to this species. The data are, however, very scanty and their interpretation is rendered still more difficult by the extraordinary individual variation in growth already described and leading inevitably to an overlapping of broods. Facts thus conspire to render it extremely difficult to reconstruct from available data the full yearly cycle. But it is essential for an intelligent appreciation of the problem to attempt such a reconstruction. If we begin with the dried fruit of the current packing season, there is every reason to agree with Lyon (1924, page 77) that simple infestation by the first brood is very slight. From this arise moths, as we have seen, in spring, which lay eggs in their turn and produce the maximum abundance of moths of the succeeding generation about Christmas. Survivors of this perhaps mixed with a few of yet another generation, give rise to the first infestation of the new packing season and thus complete the yearly cycle. Summing up, there is postulated a spring brood, and a summer brood of moths. Time would theoretically allow a second summer brood ; but this, if it exist at all, must be largely negligible or it would ensure a maximum of moths in mid-February rather than in late December.

The cycle is, of course, interrupted when the fruit infested is shipped and encounters hot weather on the voyage. At whatever time in late autumn or winter this takes place, it will lead to the pupation and later to the emergence of already grown larvae,

and to an acceleration of development in the others. The emerged moths at once begin a new and of course larger infestation and the fruit arrives in London as "grubby" as that stored in Australia till the end of January.

3. *EPHESTIA CAUTELLA* WALK.

During March, at least, when continuous observations were made in the packing sheds, *Ephestia cautella*, the fig-moth, seemed more common than *Plodia*. It was indubitably more so in the Mildura Co-operative shed, but there it was breeding plentifully in debris beneath the wooden floor, in a medium too dry for *Plodia*.

There is considerable evidence that adults of *Ephestia* are more common in late summer and autumn (say February onwards) and of *Plodia* in spring and early summer—say to the end of January—in the same packing sheds. This corresponds to distinct differences in habit. *Plodia* seems much more restricted to stored and enclosed fruit, especially that kept some time, while *Ephestia* lays much more indiscriminately and with more readiness in open boxes, in rubbish or even on drying fruit. As a factor in the London infestation *Ephestia* is almost negligible.

Ephestia is perhaps commoner than *Plodia* on cut fruits, and is, of course, the chief insect pest of dried figs. In distribution it is nearly as cosmopolitan as *Plodia*. The *Ephestia kuehniella* sometimes recorded as attacking Australian dried fruit is almost certainly *Ephestia cautella*, the former species being more especially a flour pest *Ephestia cautella* attacks chiefly dried fruits.

Ephestia definitely prefers drier fruit than *Plodia*, a preference which leads to a different behaviour in the presence of variously dipped fruit. In an experiment to determine the effect of the dip on the amount of oviposition in sultanas, the following differences, contrasting strongly with the corresponding *Plodia* results, were found :—

Boiling caustic dip	36 eggs
Modified or "temperature" dip	113 eggs
Cold dip	42 eggs

Sultanas dipped by the second method lack both the stickiness often associated with the first and the slight coating of olive oil which is an intrinsic part of the last. They therefore present the driest surface.

The eggs of *Ephestia* are nearly spherical, rather smaller than those of *Plodia*, and much more coarsely and deeply pitted, so as to appear very roughened or shagreened. They are laid usually singly, and adhere scarcely at all to the fruit ; many, in fact, lying loose among the berries and their surroundings.

The eggs appear to develop at the same rate as those of *Plodia*, but show less infertility. The later stages, however, take considerably longer than in that species, and there is no such disparity in size among larvae of similar age. Complete data on the life-cycle in Australia are not yet available.

The larvae, about the same size as those of *Plodia*, are usually more reddish, with more or less distinct longitudinal stripes of that colour, enclosing series of tiny blackish dots. Even when the stripes are absent, the lines of dots will always serve to distinguish an *Ephestia* caterpillar from a *Plodia*, save in the very early stages.

The cocoon and pupa are not importantly dissimilar to those of *Plodia*. The moth is almost uniformly grey, with a few darker hair lines.

Ephestia cautella is especially and phenomenally abundant in Western Australian packing sheds. In the Murray districts I have found it frequently in a hotel half a mile from the nearest packing shed or drying green.

Re-infestation of packed fruit by *Ephestia* seems not to take place. This is an important difference from *Plodia*.

4. *SILVANUS SURINAMENSIS* LINN.

Next to *Plodia*, the saw-toothed grain-beetle is the most abundant insect in Australian dried fruits in Victoria, South Australia and London. It is plentiful also in West Australia. Like *Plodia* and *Ephestia* it is almost cosmopolitan and attacks a host of dried food products, and it shows an even more indiscriminate taste. Like *Ephestia* it will breed in miscellaneous shed debris.

When present in large numbers it causes considerable damage, leaving very little of a sultana but the skin. It is even more essentially a storage pest than the two above-mentioned insects, and it is rarely if ever prevalent in fruit not already attacked by these primary pests. Only fruit which has been stored a long time—many months—is subject to heavy infestation by this beetle. Its presence in a packing shed is certain evidence that packed fruit has been stored too long.

The adult beetle, often known erroneously as a " weevil," is small and dark brown—nearly black—but easily recognised by the tooth-like projections along the sides of the thorax or fore-part of the body. The grub is similarly minute, equally voracious and very active.

Larvae in captivity would not settle on freshly dried clean sultanas. They seemed to prefer that soiled by the faeces of *Plodia* larvae.

The pupa or resting stage is loosely attached to the larval skin, which in its turn still hangs by the terminal pad. Pupation takes place in the midst of the fruit and without the shelter of any cocoon. The pupa is easily shaken from its attachment and may often be found lying loose among the berries. Sticky fruit which has become consolidated into a block, while less attractive to *Plodia*, is much easier negotiable by *Silvanus*, and its pupae are there much more comfortable.

The life history (egg to adult) under the most favourable conditions may be passed in as few as 22 days, but in more adverse circumstances may take 108 (Back and Cotton, 1926).

This beetle appears in more recent literature under the generic name of *Oryzaephilus*.

5. OTHER INSECTS AND MITES.

The flour-beetle (*Tribolium castaneum* Hbst.), the dried fruit beetle (*Carpophilus hemipterus* Linn.) and a small Dermestid larva have been found in Australian dried fruits in London and in Australia. The first is essentially a flour pest, and is of little importance in dried fruit.

Mr. Hill has reared two or three examples of the chocolate moth (*Ephestia elutella* Hb.) from Australian currants in Melbourne. This moth, which has not been previously authoritatively recorded from the Commonwealth, was kindly determined by Dr. A. J. Turner, who also checked the identification of *Ephestia cautella*.

Two additional species of beetles are very occasionally found in dried fruit in Western Australia, but Mr. Newman, Government Entomologist, has never seen them seriously abundant, and their presence is probably largely accidental. One of them, *Gonocephalum* sp. (kindly determined by Dr. G. A. K. Marshall) occurs on and near the drying grounds, while the other, a *Calandra* observed by Mr. Newman but never by myself, is a grain pest. (I have since seen an isolated case in London. See Appendix IV.)

Carpophilus is one of the few dried fruit insects which will breed in dropped fruit out in the open, even on the ground. In California it has even been found in the figs on the trees. It is essentially fond of moist fruit and will probably never be a serious pest of commercially dried grape fruit.

Drosophila—the vinegar-fly—is hardly a pest of *dried* fruit at all; but it will infest fruit which has been incompletely dried and has begun to ferment.

III. POSSIBLE SEATS OF INFESTATION.

1. DRYING-GREENS.

No dried fruit insect is interested in the grapes on the vine. The first possible seat of infestation is the drying-rack, and here we must be careful to differentiate between the habits of the various pests. We have seen that by far the most important of these is *Plodia*. The main problem of the investigation was to discover at what stage in the process the chief infestation by *Plodia* occurs. No belief has been more firmly fixed in the minds of many growers and packers than that in drying-rack infestation. It is therefore important to realize that, at least under present conditions of cleanliness, there is no evidence that such infestation ever occurs on a commercial scale. Personally, I have no firsthand evidence that it has occurred, but I am bound to attach some weight to declarations that the " grub " has been found in fruit on the racks, even though the only examples brought to me were caterpillars of the light brown apple moth (*Cacoecia postvittana*)—a pest of the growing vine, but not of dried fruit—and in West Australia, of *Ephestia cautella*.

We have seen that *Plodia* is essentially an indoor moth, spreading but little by its own efforts. The swarms of small moths seen near the drying-racks during the warm nights of summer probably never include a single example of *Plodia*. In the Murray settlements I have caught many of them, both on dry nights and after rain, without finding either *Plodia* or *Ephestia* among them. On the 22nd April I examined 134 moths which had been trapped near the drying-racks on Mr. Showell's property at Renmark. Although this establishment is kept very clean, the racks are so numerous, adjacent and widely roofed, and so near to the shed where infested samples are kept for immunity experiments, that if rack infestation occurs, it should be there. These 134 moths included some 20 miscellaneous species, but not a single *Plodia* or *Ephestia*.

As another check on the occurrence of drying-rack infestation, days have been spent in examining fruit on the racks (sometimes exposed five weeks or longer) and in sweat-boxes just brought to the packing sheds. In none of these cases were eggs of *Plodia* or of *Ephestia* found on the fruit. In one case in Western Australia, as described below, larvae of *Ephestia* were found on a drying rack.

When it is considered finally, as we shall see, that the ordinary stemming and grading machine effectually disposes of the bulk of any experimental infestation, *it may be definitely asserted* that so long as the present cleanliness regulations are enforced, *infestation on the drying-greens is commercially negligible.* That it may occasionally have occurred, in the past, even with *Plodia,* when old fruit was stored actually on or near the racks, and these were near sheds or houses, may be admitted, especially since de Ong (1924) records drying-ground infestation by *Plodia* in California (under conditions with which I am unfortunately not familiar). But at least two cases have come before me of fruit stored on drying-greens distant from buildings and remaining free from *Plodia* for nearly a year.

The position with regard to *Ephestia* is slightly different. Even in the Murray districts it was found that *Ephestia* was more widely ranging and could breed in rubbish that was not attractive to *Plodia.* Full-grown larvae, moreover, were found in sweat-boxes of apricots, especially " slabs " or stuck-together, over-ripe fruit in two Renmark sheds. In the Mildura sheds at night *Ephestia* showed more willingness than *Plodia* to oviposit on the fruit exposed in sweat-boxes and hoppers. Nevertheless Murray experience on the whole led to the conclusion that infestation of drying-racks by *Ephestia* was only a little less improbable than that by *Plodia.* In Western Australia conditions are widely different not only from those in the irrigated areas of the Murray, but also from those of the non-irrigated districts in the South of South Australia. Whether in an ordinary season drying-rack infestation is any more frequent than in the Murray, there are no data to indicate. In the 1927 season a very wet March led to an unduly protracted drying period, to which, in the absence of any more reasonable explanation, I attribute the infestation seen. This consisted of an *Ephestia* larva beneath a bunch of scarcely half-dried lexias and several more, full-grown, in crumpled hessians, damp with recent rains, on adjacent empty racks. The hessians evidently afforded pupation shelter, since there were empty cocoons of *Habrobracon* and apparently of *Ephestia* on them too. The racks were of a different type from those prevalent in the east, very close together and covered on top and sides with hessian. The more open eastern type would undoubtedly be less liable to infestation. Except by the adoption of dehydrators, the long drying period probably cannot be shortened, but the infestation would almost certainly be lessened firstly by the use of drying-racks of a more open type and secondly by giving up the practice of storing fruit on the growers' premises.

In West Australia I saw many cases of sweat-boxes just brought into the shed, infested with large, and sometimes full-grown *Ephestia* larvae. Doubtless a good proportion of this infestation had occurred during storage at the growers' rather than on the drying-racks. A queer feature was the absence, not only in recently arrived sweat-boxes but also in those which had been in the shed for some weeks, of most other stages than the full-grown or nearly full-grown larvae. As this was on the 9th of May it would seem that there is only one brood in dried grape-fruits in West Australia—the fruit becoming infested as the result of long drying and storage and producing only full-grown larvae by the end of the season. As such larvae are believed to be all eliminated by the stemmer and grader, we have thus an explanation of the fact that *Ephestia* is practically never frequent in Australian fruit in London. *Ephestia* is largely a pest of the pre-packing period, while *Plodia* concentrates essentially on the packed product. There is thus far less cause for alarm in the West Australian infestation than would appear at first sight. At the same time, however, the regulations and inspectors' instructions should apply to dried fruit pests, including *Ephestia,* in general rather than specify, as now sometimes occurs, *Plodia* alone.

2. PACKING-SHEDS.

Infestation, at least by *Plodia*, begins in sweat-boxes in the packing shed. Sweat-boxes kept over night before tipping into the stemming and grading machine actually represent the first stage in the handling of the fruit at which I have found *Plodia* eggs. Such infestation is, however, extraordinarily slight. Fully exposed fruit has less attraction for the moth than that relatively enclosed. This is in keeping with its liking for dark and ill-ventilated corners. Not only was sweat-box oviposition extremely slight, but the moths themselves, as shown by day and night observations, were quite rare in the packing sheds during the current packing season—February to April. More curiously still, they were more plentiful in early February, when the sheds were relatively or entirely empty of fruit, than towards the end of March. That this was not due entirely to the enforcement of the sanitary regulations and the laying down of concrete floors was shown by the still small numbers in the old wooden-floored Mildura Co-operative shed, and by the reported fact that moths were very abundant in, for instance, the concreted Birdwood shed of the same Company during late December, though extraordinarily rare in the period above mentioned. The most surprising example was that of the very clean and well-concreted Red Cliffs Co-operative shed where on the 1st April I examined stacks aggregating 1,500 tons of stored fruit without finding a single moth.

Even in the Mildura Co-operative shed, which gave me almost my only example of the conditions formerly prevailing in the industry, it was a good night when I caught 20 moths during March or later, and these were chiefly *Ephestia* which bred in the fruit debris accumulated beneath the rough wooden floors—a purely temporary state of affairs which will be changed by next season.

We have seen that the moths, especially *Plodia*, do not breed to any extent outdoors. Moreover, an emptied, cleaned and disinfected shed can no longer support a population of moths. Under present conditions, to speak approximately for the Murray settlements in general, some of the previous season's fruit is stored in the packing shed during early summer and in fact need not be cleared by regulation till the 31st January ; while about the third week in December dried apricots begin to be brought in. These apricots and peaches are in quantity entirely negligible from the viewpoint of the export industry ; but it will be seen they have ample opportunity to become infested with *Plodia* from last season's dried grape fruits. The cut fruits must be cleared with the others by the 31st January. The shed is then cleaned and disinfected and a variable gap intervenes until the arrival of the first new season's currants. I suggest that this gap be widened by putting the clearance date at the earliest moment when, in a given district, the last of the cut fruits can be removed from the packing-shed. At the same time the cleansing operations should be as thorough as is humanly and mechanically possible. The roof and higher walls should be whitewashed or sprayed with a disinfectant like Lotol.

Thus pre-packing infestation, at least by the predominantly important *Plodia*, should be almost entirely eliminated.

It would also be advantageous to order the clearance from packing-sheds of all last season's fruit some time before cut fruits begin to arrive ; in other words, insert a second close season for cleaning and disinfecting the shed. This date should be about the end of November. Following this up, and rather anticipating the next section, it may be suggested that the cut fruits removed from the sheds in January be stored in warehouses other than those which will later receive the grape-fruits of the same season. This provision would be especially necessary if the suggested clearance in November be not adopted.

Sweat-box infestation could be probably entirely eliminated by putting through the stemmer and grader all fruit the day it is received. But Mr. D. C. Winterbottom, Manager of the Mildura Co-operative Packing Company, and Mr. E. Seary, of the similar Renmark organisation, consider this would be economically impracticable. The amount of fruit coming in per day varies greatly and there would be slack days if stacks were not accumulated.

Special Note on West Australian Conditions.—A heavy infestation of the fig-moth, *Ephestia cautella*, was found in the Swan settlements on the 9th May, when half-a-day was available for their inspection. In the packing-shed—a large new and well-built one belonging to the Swan Settlers' Association—I saw the worst infestation I have encountered. Literally thousands of full-grown *Ephestia* caterpillars were crawling from the crowded sweat-boxes, and, attacked at once by the parasitoid, *Habrobracon*, which was present in swarms, were lying dead or dying on the outside of the boxes. Practically no stages other than full-grown larvae were found, and such of these as remained would almost certainly be eliminated by the stemming and grading machine. Such an infestation is utterly at variance with Murray River experience and is said to be quite exceptional in Western Australia. We have already blamed the unusually long drying period brought about by a wet March for the relatively small proportion of drying-rack infection seen. But there is one outstanding difference between western and eastern procedure—a difference in which, I am satisfied, lies the chief reason for this phenomenal infestation of *Ephestia* in the west. Whereas in the Murray settlements fruit is boxed, taken almost at once to the packing shed and there passed through the stemmer and grader with at most a few days' delay, the western Australian product is often stored in kerosene boxes in a shed on the growers' premises for as long as two months, and even after arrival at the packers it is again stacked for from two to five weeks. Apparently the individual lots are so small that such accumulation, both at the growers and at the packers, is believed necessary for the economic handling of the product. It is surprising that no such procedure is necessary, so far as I know, in any of the Murray districts. If it be really essential in Western Australia then this affords another strong argument for the centralisation of packing-sheds. Such a slow turn-over is simply tempting fate. I even saw one sweat-box of lexias from which almost every seed had been removed by mice, leaving the fruit little better than a mass of unpleasant debris. A system which allows such an occurrence should surely be changed.

Storing in sweat-boxes at the growers for more than four days, especially in sheds rather than in the open, should be forbidden. Until Western Australia finds a means to hurry up the progress of the fruit from the rack to the final package it might be advisable to accord its fruit special treatment and certainly special examination, before it is placed on the London market. Although it appeared probable that, owing to the combined action of the natural enemies (*Habrobracon* and ants) and of the stemmer and grader, but little if any of the 1927 heavy *Ephestia* infestation would be carried to London, yet the congested condition of the sheds owing to the accumulation of sweat-boxes of fruit was infallibly leading to a *Plodia* infestation heavier than any that need be expected in the Murray packing-sheds.

To sum up this section it may be stated that, so far as the most important pest is concerned—namely *Plodia*—the most fundamental result of the investigation is the discovery that the *bulk of the infestation occurs after the fruit is packed.*

3. STORAGE-SHEDS.

Plodia is essentially an inhabitant of storage sheds. Large accumulations of dried fruit, little disturbance, scanty ventilation and lack of strong light are all factors extremely favourable to this moth.

In London, as indicated in my first report of September, 1926, the storage warehouses for dried fruits are heavily infested with *Plodia*.

In storage-sheds as in packing-sheds, a concrete floor should be regarded as the first essential, though of course one would make an exception in the case of the beautifully insulated chambers of the Government Cool Stores at Melbourne, which are apparently moth-proof though wood-lined. The boxes should be stacked on dunnage on the concrete.

So far as Melbourne is concerned, the amount of export dried fruit stored there has been almost negligible, though in 1927 a large increase was expected. The more of this increase that can be taken up by the above-mentioned Government Cool Store the better. In this store the fruit would, of course, not be refrigerated. Not only were the chambers at this store in 1927 free from moths, though they would doubtless soon be infested by incoming fruit, but they can be fumigated if necessary at a few minutes' notice, which is not the case with most of the smaller stores.

In Adelaide conditions are very much less satisfactory. This is the more unfortunate since the bulk of the Adelaide crop is stored at Port Adelaide while awaiting shipment. The fruit is stacked in various sheds, along with other and miscellaneous merchandise often under conditions extremely favourable to pests. In one case, new sultanas were piled near dried apricots which had been there over three months and were badly infested with *Plodia* and *Ephestia*. It was only a question of time before the grape fruits would be attacked in their turn. Some of the stores were gloomy cellars with abundance of moths—more in fact than I had seen anywhere else in Australia.

It would be advisable to clear and disinfect all such stores at least a month before any new season's produce is received. This is already done by Geo. Ferguson & Co., who store for Gollin & Co. They clear the fruit by the end of November and disinfect by a method that is entirely satisfactory save that the upper walls and ceiling are not treated. These should be sprayed with Lotol or whitewashed.

I am assured by Mr. R. P. Allen, Chief Commonwealth Fruit Inspector, that Port Adelaide conditions may be regarded as purely temporary. I earnestly recommend that storage-sheds for export dried fruit there and elsewhere be brought under exactly the same hygienic regulations as the packing-sheds themselves. At the same time it must be recognised that the opportunities for infestation in some of the London warehouses are very much greater than any I have seen at any stage in the handling or storing of the fruit in Australia itself or on shipboard. It would seem that either these warehouses must receive careful attention or the fruit be packed in an insect-proof container.

In 1927 the position with regard to the London warehouses was very greatly improved by the restriction of their number, for Australian dried fruit, to four. These were at the end of June clean ; but whether it is possible to keep them so remains for this season to show.

4. SHIPS' HOLDS.

In spite of the fact that the moth is cosmopolitan and is probably frequently brought on board in ships' stores, the risk of primary infection during the voyage from Australia to England is almost negligible. As mentioned in the report of August, 1926, " The ships'

holds seem hardly to offer favourable breeding quarters, the steel structures are kept clean and the whole frequently fumigated, while storage space occupied by dried fruit on one voyage may carry on the next materials quite unsuitable for breeding the moth."

There is, however, a very real danger of second brood infestation, during the hot weather of the tropics, in fruit already containing some stage of the moth when embarked. In order to study the conditions usually experienced by dried fruit in oceanic transit, something under 500 tons of ordinary commercial shipment, from Melbourne, Adelaide and Fremantle, were carried on the R.M.S. " Orama," stowed, through the kindness of the authorities, in a variety of situations. The bulk was stacked in No. 1 hold, upon ingots of lead, whence the piles reached through three successive decks. As the intervening hatches were not inserted, the fruit in the middle was piled about 50 boxes deep—elsewhere from 15 to 25. This was battened down throughout the voyage save when opened sufficiently for me to slip through, and in consequence it retained an unexpectedly low temperature. No. 3 between decks contained fruit from Melbourne and from Adelaide, standing on a hatch above cold storage chambers. Though this hatch was caulked and insulated with three inches of sawdust, the proximity of the refrigerated hold kept the between decks at an unusually low temperature. Finally, the cartons and a quantity of fruit from all three ports were stored in No. 5 hold which served also as a baggage room and as such was opened five days a week. Here, and here only, were the tropical temperatures able to affect materially the stored fruit.

Through the kindness of the Chief Engineer and his staff, arrangements were made to take some twenty temperatures in these holds every day—No. 5 at 9 a.m. and the other two at 11 a.m. The temperature of the sea-water was also recorded, as more likely to affect the closed holds than that of the atmosphere. These observations were continued from Fremantle to London, the figures after Toulon being due to the refrigeration Engineer and to the baggage-master. In No. 5 hold two hanging thermometers were used ; in No. 3 four hanging ones, two low and two high in position, and, placed near the ceiling, six terminals of a distance thermometer ; and finally in No. 1 six of the latter as in No. 3, and two hanging thermometers. Save in No. 5, which was entered daily, the hanging instruments were pulled up through chutes to a higher deck for reading.

The following table gives the temperatures of the three holds in question from Fremantle to London. In the figures for No. 1 hold, the first and second columns refer to hanging thermometers on port and starboard respectively, while the rest are electric distance readings. In No. 3 the first column refers to a high hanging thermometer (port) and the second to a low one, while the third and fourth indicate similar readings on the starboard. The remaining figures are those of the distance thermometers. In No. 5 the two columns are from hanging thermometers, placed about half-way between floor and ceiling, on port and starboard respectively.

No insects were seen in No. 1 hold save a few houseflies, a few *Drosophila* from a single box of fermented, imperfectly dried lexias, and a very few *Plodia* moths which emerged from the fruit, one on 26th May and three or four others when the hold was opened at London. The fruit was all Victorian, and apparently clean on shipment.

No insects whatever were observed in the much cooler No. 3 hold, which contained Victorian and South Australian fruit.

In No. 5 hold, where fruit from three states was stowed, 3 *Silvanus* beetles were crawling on West Australian boxes a day after leaving Fremantle. A male *Plodia* moth emerged from a box of West Australian two-crown currants on 13th May. Three more moths

R.M.S. "ORAMA." HOLD TEMPERATURES IN °F.

1927.	No. 1 Hold.								Average.	No. 3 between Decks.										Average.	No. 5.		Sea-water.
May 10th ..	63	71	61	62	62	62	58	?	61	58	46	58	46	58	57	58	58	59	?	55	69	69	75
11th ..	65	62	61	63	61	64	62	59	62	59	46	56	47	59	58	58	58	58	59	56	72	72	75
12th ..	66	67	63	62	62	63	61	59	63	60	44	58	45	60	59	59	60	61	62	57	75	75	75
13th ..	67	70	64	63	64	64	63	60	64	60	45	58	46	62	60	60	61	61	62	58	79	79	79
14th ..	67	71	64	64	65	64	64	60	65	62	45	59	46	62	60	60	63	62	64	58	82	82	82
15th ..	68	73	66	64	65	66	63	59	66	62	45	60	46	62	60	60	62	61	62	58	Sun.	Sun.	83
16th ..	69	74	67	65	66	68	64	61	67	64	45	60	47	65	62	63	64	64	65	60	85	85	83
17th ..	70	74	68	65	67	67	64	60	67	70	49	63	50	74	69	70	67	66	68	61	86	86	84
18th ..	COLOMBO.																						
19th ..	72	81	70	67	69	71	66	62	67	70	50	68	52	72	69	70	74	73	75	67	87	87	82
20th ..	72	81	71	68	71	71	67	63	71	70	49	69	54	73	69	71	74	74	75	68	87	87	83
21st ..	73	81	72	70	73	73	68	64	72	72	50	71	54	75	72	73	78	76	80	70	87	88	85
22nd ..	73	82	72	70	73	73	69	64	72	71	49	70	51	74	71	73	76	74	76	69	Sun.	Sun.	85
23rd ..	74	83	72	69	72	72	68	64	72	72	50	69	52	73	70	72	74	73	74	68	89	90	84
24th ..	74	82	72	69	72	72	68	64	72	72	50	68	52	72	70	71	73	73	74	68	89	90	85
25th ..	75	83	72	70	72	73	69	64	72	72	50	68	52	74	70	72	74	72	74	68	91	92	84
26th ..	75	84	74	70	73	74	69	65	73	72	48	70	51	74	71	73	76	75	76	69	91	92	85
27th ..	76	84	76	73	75	77	72	67	75	72	51	74	56	77	73	75	80	79	80	74	91	89	80
28th ..	75	81	74	72	72	75	70	66	73	70	49	70	53	72	70	70	73	72	73	67	—	—	73
29th ..	PORT SAID.																						
30th ..	75	77	73	71	71	73	70	66	72	64	55	64	60	63	66	64	64	65	66	63	83	82	71
31st ..	74	74	72	71	70	72	70	66	71	64	55	62	59	62	64	62	63	64	66	62	81	81	67
June 1st ..	NAPLES.																						
2nd ..	73	76	72	71	70	72	70	66	71	62	55	60	59	60	62	60	60	61	62	60	78	77	66
3rd ..	74	75	71	71	70	71	?	66	71	60	57	60	59	60	60	59	60	61	?	60	76	76	?
4th ..	74	74	70	70	69	71	69	66	70	55	50	57	55	59	61	59	59	60	61	58	74	74	?
5th ..	73	74	71	70	69	71	70	66	70	60	54	58	55	58	60	58	58	59	60	58	72	72	?
6th ..	73	74	70	70	69	70	69	66	70	60	55	58	58	58	60	58	58	59	60	58	70	70	?
7th ..	73	74	69	70	66	69	68	65	69	55	55	58	56	55	58	55	55	56	57	56	68	68	?
8th ..	71	69	69	70	66	69	69	66	69	56	54	53	52	54	55	54	53	54	55	53	68	68	?
9th ..	70	69	69	69	67	68	68	66	68	51	50	52	50	52	54	52	52	53	54	52	—	—	?

emerged on 17th and a similar number on 19th and 20th. On 24th larvae of *Plodia*, fully-fed, began to crawl out of the West Australian currants, and adults of their parasitoid, *Habrobracon*, began to appear. From then until arrival in London moths and parasites became increasingly plentiful. No *Ephestias* were seen. As many as 60 *Habrobracons* were observed killed at the light in one day. As regards contamination of other fruit in this hold, the cartoned fruit, much of which was exposed by rents and bursting of the containers, examined on 14th June, showed no signs of infestation; but nevertheless such probably takes place.

The results from these three holds are not strictly comparable, since the much more heavily infested West Australian fruit was stowed all in one place; but the fact that practically all the moths which did emerge in No. 1 hold did not do so until the very end of the voyage shows a retarding effect of the lower temperatures which prevailed there. As regards No. 3 hold, in which no moths appeared, it is hardly likely that the fruit was entirely free; but rather more probable that development was retarded even more than in No. 1.

It does not seem likely that relatively cool storage like that obtained in No. 3 hold could be secured for the whole export crop, but storage in the baggage-room, where frequent opening gives full effect to the tropical temperatures, should be avoided. On the present voyage the fruit was thus stowed largely for the convenience of the investigation, and for direct experimental purposes. Stowage (*a*) on hatches between decks above the refrigerated chambers, and (*b*) in lower holds which remain closely battened down for the whole voyage, should be regarded as optimum for dried fruits, and should be secured for them when possible.

IV. CONTROL MEASURES.

1. DIRECT.

(*a*) *Natural Enemies.*

Biological control, involving the utilisation of the natural enemies of insect pests, is rapidly becoming the most efficient and economical method available to the entomologist. Unfortunately the wide distribution of most dried fruit pests, especially *Plodia*, and the fact that their chief natural enemies have in most cases accompanied them, render these insects perhaps less amenable to such means of control than any others. But while realising that we probably can neither introduce new enemies for such pests nor do much materially to encourage those already in Australia, we must recognise that very great good is already being accomplished by these latter. (Hase, 1922, 1923, 1925.)

The most important natural enemy of *Plodia* is a small black Braconid wasp, *Habrobracon juglandis* Ashm. (*Microbracon hebetor* Say) (determination kindly checked by Mr. D. S. Wilkinson) which, having first paralysed completely the full-grown *Plodia* larva lays upon it a number of eggs. The egg is opalescent whitish, long and narrow, about the length and thickness of one of the victim's legs. Three to seven eggs may be laid on one caterpillar, loosely attached to the skin, usually on the side which happens to be undermost. From these eggs hatch small legless larvae which proceed at once to feed on the caterpillar, which remains immobile save for the beating of its heart. Feeding finished and the *Plodia* almost or quite consumed according to the number of *Habrobracon* grubs exploiting it, these later pupate on the spot, spinning each for itself a tiny, close-textured,

shining white silken cocoon, usually on the adjacent fruit. In boxes which have been well hunted through by these active and industrious little wasps, these cocoons, full or deserted, are often almost the only sign that *Plodia* has once been present.

On stacks of stored fruit, and in the boxes themselves, one often finds numbers of limp, motionless, full-grown *Plodia* and *Ephestia* larvae. These are ones which have been paralysed in the usual way by *Habrobracon*, which has omitted, however, to lay eggs on them. The first care of the parasite, when it has stung and paralysed its victim is to feed itself by sucking at the original puncture and often at several subsequent ones. Egg-laying may or may not then follow. From an economic viewpoint the result is the same, since such paralysed larvae never recover, even though they may not actually die for a month or more. In one of the Port Adelaide stores there were literally hundreds of such caterpillars on the stacks of boxes or dried apricots, while in a large Western Australia packing-shed every full-fed *Ephestia* larva which crawled out of the sweat-boxes seemed to be attacked at once by the swarms of parasites which flew there. In the latter shed some of the windows were black with adult parasites.

In Mildura *Habrobracon* seemed definitely to prefer *Plodia* to *Ephestia* larvae, but it readily paralyses the latter even though omitting to lay its eggs on them ; and as we have seen, *Ephestia* in West Australia was parasitised on a large scale. Younger larvae of neither species are attacked. It seems probable that there are two biological races, one specialising on *Plodia* and the other on *Ephestia* ; but further study is required to elucidate this.

I have found *Habrobracon* in England and in Australia wherever *Plodia* was present. Over its host it has a great advantage in that the complete life-cycle in the Australian summer and autumn (two lots at Mildura in March) can be accomplished in 20 days. Unfortunately, however, it usually has fewer offspring than *Plodia* and attacks its host at only one stage of the latter's life-cycle.

In Australia *Habrobracon* has been studied in painstaking detail by Mr. H. Showell who suggests that its presence " accounts for the well-known fact that in some years dried fruit keeps clean much longer than in others."

A somewhat similar, but much smaller parasitoid wasp, *Cephalonomia* sp. (Bethylidae, kindly determined by Dr. Waterston), treats the saw-toothed beetle (*Silvanus*) in very much the same way. These minute black wasps assault the full-grown *Silvanus* grubs with fury, while the grub makes a series of sharp galvanic jerks in the attempt to dislodge its tiny foe. The sting which brings about paralysis is dealt with lightning rapidity, but there is still considerable struggling before immobility supervenes. The egg is glued securely to the side of the prey, two to three eggs on one host. As in the case of *Habrobracon*, the full-fed grubs spin each a little white cocoon, much smaller than in the former and of a more rounded shape. From eggs found but not actually seen laid, on 15th March, adults were obtained on 14th and 15th of April ; so that in the Australian early autumn the life-cycle is apparently accomplished in about a month. I have seen this parasite only in Australia.

Not by any means to be despised as enemies of the " grub " are the ants of the genus *Iridomyrmex*, so richly represented in Australia. Especially useful are *Iridomyrmex detectus* Sm., the " meat ant " and *I. rufoniger* Lowne (kindly determined by Mr. J. Clark). Where fruit, as in sweat-boxes, is exposed to their visits it may be almost completely

cleared of pests. There is distinct evidence that the "meat ant" prefers *Plodia* to *Ephestia* larvae, but will take the latter when the first is not available. There is often a continuous file of ants, bearing grubs, from infested stacks of fruit to a nest, in one case thirteen, in another fourteen yards distant.

(*b*) *Machinery.*

The ordinary stemming and grading machine, which receives the fruit soon after it arrives in sweat-boxes at the packing-shed and removes stalks and foreign matter generally, was tested with counted infestations of *Plodia* and *Ephestia*, to examine the mechanical effect on the various stages of these insects. The eggs were given most attention since they are the most likely stage to occur on sweat-box fruit and since also they were presumably the least likely to be damaged by the machine.

Experiment I. *Plodia* and *Ephestia* moths were induced to lay 198 eggs on 21 lbs. of sterilised sultanas. The fruit was then put through the machine in the ordinary way and the cleaned product duly examined. Twenty per cent. of the eggs were found to have passed through the machine, but only 1½ per cent., namely 3 eggs, were uninjured and able to hatch. Only one of these three was an *Ephestia*.

Experiment II was managed in the same way, but a larger number (1072) of eggs was secured, thus enabling infertile, *Plodia* and *Ephestia*, to be differentiated with advantage. In order to make this more detailed count the fruit was quartered down like a soil sample for analysis, to one-eighth, giving the following totals :—

Fertile *Ephestia* eggs	296
Infertile ,, ,,	16
Fertile *Plodia* ,,	720
Infertile ,, ,,	40
Total	1,072

After machining, the fruit was examined again in the same manner, giving :—

Uninjured *Ephestia* eggs	8
,, *Plodia* ,,	72
Injured ,, ,,	24
Total	104

The "infertile" or "injured" totals include not only those eggs whose collapsed appearance showed them to be infertile, but also those in the first count which were crushed during quartering, and those in the second which had been crushed in the machine. In the second count therefore the greatly increased (6 times) non-hatching of *Plodia* eggs may be due to several causes, for collapsed or crushed eggs adhere more firmly to the fruit than sound ones and are more likely to pass through the machine. It is therefore not possible to analyse the above figures very exactly. It would seem, however, that less than 10 per cent. of the eggs pass through the machine and the proportion hatching, of those which do, is small ; so that we are probably justified in claiming that the stemming and grading machine disposes of about 95 per cent. of the viable eggs.

Plodia eggs are much less easily knocked off than the only slightly adhering ones of *Ephestia*. In the second count of Expt. II the 8 eggs total of *Ephestia* is almost certainly false since it is based on one egg which came through sticking to the exuding pulp of a crushed berry.

Of 163 larvae, from one-third to full-grown, chiefly *Plodia*, not one went through the machine, either dead or alive.

The new blending machine, invented by Mr. H. Showell, and operating in the packing shed of the Renmark Co-operative Company, involves a preliminary shaking as violent as and additional to that of the ordinary stemmer. It is probable that this additional agitation will materially decrease the percentage of eggs passing through uninjured.

It is thus interesting to note that the ordinary stemming and grading machine is practically as efficient a steriliser as the best fumigant known to me.

(*c*) *Trapping.*

There has been so much discussion and advocacy of trapping, that it was very disappointing that, owing to the scarcity of moths at the time, I was unable to test its efficacy. At the outset it may, however, be definitely asserted that the use of lures on the drying greens is perfectly futile. It is in the packing sheds and especially the storage warehouses that it may probably be advantageous.

Neither *Plodia* nor *Ephestia* is much attracted to light—not by any means so much as is their parasite, *Habrobracon*. But pans of liquid, lighted by a swinging hurricane lamp or not, have been found to attract certain numbers in the Mildura and Renmark districts and in England (Knapp, 1923, *Ephestia*). Various sheds have tried a number of different liquids, including water, sweet flour paste, grape juice, tea with or without milk, water with kerosene layer, phenyle, sour flour paste, pear juice.

Knapp suggested tea, prepared with milk and sugar as for human consumption. This suggestion was followed in Mildura, and also independently tried at Renmark. For a careful experimental study of various lures and lure materials we are indebted to the Irymple Packing Pty. Ltd., under the management of Mr. Peter Malloch. In this shed, 9,837 moths were caught in the period from 22nd October, 1926, to 24th January, 1927, and at the same time a very detailed record was kept of the catches and the prevailing weather conditions. It is significant that these captures were made before the shed was concreted. Tea without milk or sugar was found to be much more effective than any other lure while four large pans were found to attract more proportionately than ten small ones with greater aggregate surface of liquid. The large pans were 18 inches square, while the small ones were kerosene tins cut lengthwise.

Owing to the scarcity of moths in the 1927 season or at least during February and March, I was unable to ascertain whether the moths formerly caught at lures were ovipositing or mating individuals, whether they were all of one sex or even whether they were all fruit-moths or not. Some indication of the percentage of the moth-population caught by liquid lures was given at the Mildura Co-operative shed, where, during a whole week-end, two traps caught two moths, although 20 could be caught in an evening with a net.

But in spite of our present ignorance of the state and identification of the moths, and as to the percentage of the total shed population caught in this way, it would probably be worth while to continue the use of lures, with plain tea, in cases where the moths continue plentiful in spite of all preventive measures. The preventive measures must, however, be ever the first consideration.

(*d*) *Sterilisation.*

As will be shown later, the one essential measure which almost certainly must be adopted against insect pests of dried fruit, is insect-proof packing. Whether wholesale sterilisation at or before packing will be necessary is less certain. We have seen that pre-packing infestation, at least with *Plodia*, is almost negligible and that the ordinary stemmer and grader reduces an experimental infestation, even of eggs, by about 95 per cent. Insect-proof packing alone would, then, enormously reduce infestation. It is not possible yet to decide the question of sterilisation. One would like to see first the effect of further hygienic measures, as suggested above, and of insect-proof packing on a large scale. Further shipments of sealed fruit will be examined in London this season. (*See* Appendix IV.)

Heat sterilisation.—If sterilisation should prove necessary then I have no hesitation in recommending a heat process as the most efficient and the most economical. We have seen that the stemming and grading machine eliminates most of an infestation save some of the eggs. Most good fumigants will destroy the larvae, but few or none will with certainty destroy *all* the eggs. A heat method, on the other hand, kills eggs more easily than any other stage of the insect. A heat method, therefore, seems undoubtedly the most suitable in the present case.

There are three questions to consider at the beginning—firstly, the minimum temperature required to destroy *Plodia* eggs, and other stages, secondly, the time during which they must be held at that temperature, and thirdly, the maximum temperature which the fruit will endure without injury. Taking the last point first, I am assured by Mr. E. Seary, Manager of the Renmark Co-operative Fruit Packing Company, that he has dehydrated grape fruits for periods of many hours at a temperature of 180° F. without injury. It must be remembered also that the sun temperature in the Murray fruit-growing districts in the drying-season, is sometimes as high as 170° F. Parker (1915) gives 180° F. as a temperature which will kill all stages of *Plodia*, while Lovett (1921) found 125-130° F. sufficient. Goodwin (1922) found no insect egg which, newly deposited, would hatch after subjection to 180°-190° F. for 20 to 30 minutes, while older eggs were nearly all killed at 1° F. higher. Knapp (1923) killed larvae of *Ephestia kuehniella* by subjecting them to 120° F. for 20 minutes. Lyon (1926) found 145° F. for five minutes sufficient to kill all stages of the "principal pests" of dried fruit. Mr. G. F. Hill, in his unpublished results, obtained progressive reduction of fertility in *Plodia* eggs when the temperature increased above 95° F. Quayle (1926) killed *Plodia* larvae by a heat of 130°-140° F. for one hour.

Fumigation.—We have seen that fumigants are very seldom wholly efficient against eggs. For a food-product which, like dried fruit, contains considerable moisture, the choice of fumigants seems strictly limited. As with any other method of sterilisation, fumigation is in the long run useless unless it is followed up by insect-proof packing. There seems a tendency in London to regard successful fumigation as solving the problem ; but it is important to realise that fruit thus cleaned is liable to infestation again in a few days at most. If the fumigation is done in autumn, of course, re-infestation will be negligible until the following spring, by which time the fruit will in many cases have been consumed. No fruit, however, can be guaranteed clean which has not been secured, by packing or storage methods, against re-infestation.

For practical purposes there are two main types of fumigants offering the most hope of success—carbon bisulphide under partial vacuum conditions, and the gas of secret composition which Mr. Plumbridge is employing on Australian dried fruit in London. I have already reported on the latter that it is the most efficient fumigant for dried fruit insects known to me. It apparently kills the total of all stages except the eggs,

of which it destroys 98 per cent. Hitherto the cost of the Plumbridge treatment has been about 25 shillings per ton, but organisation on a larger scale would doubtless reduce this, and in fact, during the 1927 season, I believe it is hoped to fumigate for 15 shillings or even less. If fumigation be decided on there is no doubt that the Plumbridge System is the most efficient and the simplest at present known.

During the 1927 season it was being employed on all Australian fruit immediately on arrival in England. Impressed by the evidently already good effects of the cleaning-up campaign in Australia, and by the scarcity of *Plodia* in the packing sheds, I suggested that only those lots should be fumigated which representative sampling showed to be infested. According to Mr. W. P. Caro, however, adequate sampling is an expensive process—in some cases more so than wholesale fumigation Therefore, since the fruit, though much cleaner in the 1927 season, still contained some "grubs" (*see* Appendix IV), it will be necessary to continue to fumigate the whole importation until insect-proof packing is generally adopted. There is at present a suggestion of small cartons, for publicity purposes, to be packed in London. I earnestly recommend that these be made insect-proof by simple paper sealing. Thus, and thus only, can the consumer be guaranteed insect-free fruit.

Carbon bisulphide.—Mr. A. V. Lyon obtained wholly favourable results, even killing all the eggs, by the use of carbon bisulphide in partial vacuum, using the cylindrical steel drum from California installed at Sarnia (Mildura) packing shed by the A.D.F.A. This cylinder is 4 feet in bore and 10 feet long, holding two tons of dried fruit ready packed in 56 lb. boxes. The air was exhausted to one inch of mercury on the gauge attached and carbon bisulphide introduced through a valve till atmospheric pressure was restored. The air was exhausted in 4 minutes, and replaced by carbon bisulphide and air in 4½ minutes. The fruit was then left in for 1¾ hours.

Hydrocyanic acid is not recommended as a fumigant for dried fruit in bulk. Its penetrative power seems not sufficient to kill insects deeply buried in packed fruit, while there are objections to its use on a food product of fairly high moisture content.

To sum up the question of fumigation, whatever method be employed, unless one is prepared to repeat the process at intervals, the fruit must first be packed in insect-proof containers. The good effects of one fumigation will then be conserved, wherever the fruit be stored, until the package is finally broken.

Cool Storage.—The Victorian State Department of Agriculture is carrying on experiments in the use of cold storage (*e.g.* at 25° F.) to retard the development of dried fruit insects. Similar work has been done also at Adelaide, where it was claimed (Quinn, 1926) that after storage at 33–36° F. for nine months, fruit remained for several months uninfested after removal into a room at ordinary temperature where the pests were known to occur. Yet according to Knapp (1923) both Guppy and Booth froze larvae of *Ephestia* till they clinked like a piece of glass, without finally affecting them. The Californian workers suggest cold storage to protect hold-over fruit during summer and autumn. Thus de Ong (1924) found that a temperature of 45–50° F. stops feeding, prevents re-infestation and, if continued three months, kills 91 per cent. of the larvae and pupae of *Plodia* and all adult beetles (*Silvanus*) in raisins.

So far as Australian conditions are concerned, the principle is sound in that it seeks to cancel out the climatic disadvantages undergone by Australian fruit during the long hot voyage and storage in England in the summer. But the cost, at least at the low

temperatures used by the Victorian Department, would seem prohibitive so far as the export quantity is concerned. In Melbourne storage for five months cost two shillings per box. Lyon (1924, page 79) writes that cool storage " cannot be recommended, as it adversely affects the quality of the fruit." But fruit examined by myself, in company with Mr. Meeking, Chief Fruit Inspector of Victoria, seemed quite uninjured by the temperatures used ; and these would seem, from Californian experience, to be unnecessarily low.

The State Authorities have promised me a copy of the final report on these cool storage experiments.

Cool storage by refrigeration during the voyage would undoubtedly prove too expensive for general adoption by the dried fruit industry, and would have no effect on subsequent infestation in England.

2. INDIRECT CONTROL MEASURES.

(*a*) *Cleanliness.*

I have read copies of the Commonwealth regulations for the cleanliness and control of growers' premises and of packing-sheds, and have seen them enforced during the 1927 season. These regulations, which are entirely admirable, should be extended to apply to storage-sheds also. In my opinion the substitution of concrete floors for the old wooden ones was the most important step yet taken in the control of Australian dried fruit insects. There seems no adequate reason why sheds for the handling and storing of dried fruits should not be as scrupulously clean as a dairy factory.

It would be a pity if the statements made above as to the commercial negligibility of drying-green infestation led to any slackening of the regulations regarding cleanliness of such places. The statements in question refer only to conditions brought about in the 1927 season, perhaps largely by enforcement of these regulations.

Should a carton container prove desirable I presume the necessary alterations and amendments could be arranged in Rule 31 (Statutory Rules, 1926, No. 22—Commerce (General Exports) Regulations, page 15), which regulates the type of container to be employed.

While every effort should be made to keep the packing-sheds as clean as possible of accumulations of rubbish, it should also be recognised that undue congestion of the fruit itself, whether in sweat-boxes or packed in the final cases, supplies additional breeding-places for pests, and by interfering with light and ventilation affords much shelter to the adult moths. It is a definite hygienic measure to keep the fruit moving as much as possible. This applies especially to West Australia.

I have not been able to find any of the dried fruit insects breeding in the stems and rubbish blown out of the shed from the stemming and grading machine ; but we know that most of the eggs, if present, are removed in this process and there is always the risk of their hatching unless the rubbish is either burned or, if used for paths, spread sufficiently thinly in the sun. No infestation was examined in quantities of *marc* or solid distillery waste examined. This material is attractive chiefly to the vinegar-fly, *Drosophila melanogaster*.

(*b*) *Deterrents.*

The number of growers and others who have experimented with various secret processes to confer on dried fruit immunity to insect attack, is remarkably great when one considers the grave suspicion with which the London market views the slightest alteration in the appearance, smell, taste, or feel of the product.

The most successful deterrent examined by me was that invented by Mr. H. Showell, of Renmark. I am satisfied that his liquid application to sultanas keeps the fruit free from primary infestation for as long as two years, even when exposed to heavy infection, though in the latter case the immune fruit is liable to be soiled by the webs and faeces of wandering full-fed larvae. Mr. Showell's experiments have been conducted in a rigidly scientific manner.

The liquid, of which the composition remains a secret, is practically tasteless, but gives the fruit a shining appearance, and renders it darker in colour and slightly duller in taste. Knowing the strong conservative feeling in London, I cannot recommend the adoption of such treatment save as a last resource. It will, however, be tried on a commercial scale this season, since Mr. Showell has treated many tons of his own fruit for export.

At the special request of Mr. R. P. Allen, Chief Fruit Inspector for the Commonwealth, a process invented by Mr. F. J. Gelly was also examined by Mr. Lyon and myself. This consists in the addition of some secret ingredient, believed to be a mineral salt, to the dipping fluid for sultanas. There is thus no additional handling of the fruit. There results no appreciable difference in colour, taste, or smell. A sample tested, with a number of *Plodia* and *Ephestia* moths, showed 301 eggs, while the control sample received only 104. Three weeks later these two samples were again examined, and healthy larvae found on both, 37 in the treated sample and 18 in the control, while three eggs taken away with me from the former (and not included in the 37) hatched and are still alive and feeding at the time of writing nearly eight weeks afterwards. The reduced numbers of insects in both samples were due partly to infertility of some of the eggs and partly to raiding by the small ant, *Iridomyrmex* sp., and by a species of mite. The results show conclusively that the treatment not only fails to deter oviposition, but rather attracts it, and checks in no sense the development of the resulting larvae. The experiment is being continued under Mr. Lyon's care until development is complete, and a bulk test is also under way with a 56 lb. box of treated fruit exposed in a highly infested cage. Personally I consider the experiment has gone far enough to condemn the treatment as entirely valueless.

(*c*) *Quick Handling.*

An important factor in the production of a heavy infestation is stagnation brought about by unduly long storage at any stage. It is highly advantageous to keep the fruit moving as rapidly as possible, from rack to sweat-boxes, from packing-shed to store, store to ship, and warehouse to consumer. The system of accumulation, both on growers' premises and in the sheds, in vogue in Western Australia cannot be too strongly condemned. A long drying-period consequent on those unfavourable weather conditions which are more likely to occur in non-irrigated, than in irrigated, districts is often unavoidable, but surely all the subsequent delays mentioned can be obviated by thorough organisation and if necessary by centralisation. Sweat boxes ought not to be kept in the shed longer than four days before being emptied into the stemmer and grader.

(*d*) *Packing Methods.*

Christie and Woodworth (1923) have stated "The logical control of insects in dried fruits lies in the use of absolutely insect-proof containers following destruction of all insect life by heat or fumigation." When, as in the Australian dried fruit industry, the bulk of the infestation occurs *after* the fruit is packed the use of insect-proof containers appears even more clearly as the one logical means of control. It is even possible, provided the present hygienic regulations continue to be rigorously enforced, that sterilisation before packing in such containers will not be necessary. It is true that the Californian industry still finds it necessary to sterilise before packing, but I have found so little pre-packing infestation in the Murray settlements that I am led to suppose that some difference in Californian conditions renders their fruit more liable to such infestation. It is hoped that the question of the necessity of sterilisation will be answered by the examination in London of trial shipments this season. In the meantime, it is important to realise that the fundamental element in the elimination of the pest is the insect-proof container, which constitutes at once a preventive and an insurance. Whatever method of direct grub destruction be employed, there are only two ways by which the effect can be rendered lasting—the use of insect-proof boxes and the treatment of the fruit with repellents. No example of the latter which I have seen is free from objections on the score of injury to the appearance or quality of the fruit.

Four main types of insect-proof containers for dried fruit suggest themselves. All have been, or will soon be, used experimentally for the Australian product.

Firstly—*Tins.* The far eastern trade already demands Australian dried fruit to be packed in soldered " tin " boxes which fit as lining the ordinary 56 lb. wooden boxes. No attempt is made to sterilise before packing. There can be no question that these are effective, and probably easier to pack than any of the other forms suggested. Their cost of 3s. 6d. each is, however, prohibitive, even though considerable reduction for bulk trade be possible.

Secondly—*Small cartons.* These are simple, sealed thin card containers, of one or two pounds' capacity. It is in such that most of the Californian "raisins" (Sun-maid) are repacked after arrival, for distribution in England. My suggestion of these to the leaders in the Australian industry has met with no encouragement. There are two main objections —firstly, the great cost, both for material and for labour, and secondly, the risk that Australian fruit would soil and soften such containers more than does the undipped Californian product. The latter risk would probably be very great if the cartons were packed in Australia, where also the higher labour costs would render their employment dearer. If, on the other hand, the packing were done in England, preliminary sterilisation would almost certainly be essential. The outstanding advantage of such cartons is that they may be attractively printed with brands and advertising matter to ensure that the smallest consumer can obtain fruit guaranteed both Australian in origin and insect-free. Until they reach the retailer they are, of course, packed in 56 lb. and 28 lb. wooden boxes only very slightly larger than those now used.

Thirdly—*Paper envelopes* fitting inside the present wooden boxes. Most, if not all of the Californian bulk fruit arrives in London in this type of container—the envelope being a tough brown-paper bag sealed at the top with sodium silicate. The boxes themselves are of sugar-pine, very well made and holding 25 lb. Seeded raisins from California sometimes arrive in similar envelopes made of bitumen paper.

Unexpected difficulties met in the attempted manufacture of envelopes in Melbourne by Messrs. Sands and McDougall, have prevented a trial shipment of one ton arranged to accompany me to England, but it is hoped that these will be overcome in time to make

the experiment later in the season. The question will have to be settled as to whether Australian fruit, which, in the case of sultanas at least, being dipped, is stickier than the Californian product, must necessarily be packed in waxed paper—such containers being much more expensive and difficult to make if waxed. The bulk of the Australian fruit is shipped in 56 lb. boxes, and it is much more difficult and expensive to make an insect-proof envelope for these than for smaller cases.

I was much impressed in London by the effectiveness of the Californian envelope, and I still feel that this method is the most promising if economically practicable in Australia. In London I examined such fruit which had remained free from infestation after seven months' storage in a heavily infested warehouse.

The trial envelopes made earlier by Sands and McDougall in Melbourne were quite unsuitable since it was almost impossible to seal them securely. It is important to realise that the partial paper linings used in the present boxes are insect-proof as far as they go, but are not complete envelopes. The perforations seen in these when the fruit has been badly attacked are due to larvae boring outwards. They are never made by young larvae seeking ingress.

Fourthly—*Cardboard containers*. These are 56 lb. and 28 lb. boxes of more nearly cubical shape than the present wooden ones, than which they are somewhat cheaper. They are rapidly and effectively sealed by three bottom and three top strips of stout, strongly-gummed brown paper, which may be procured in convenient rolls for the purpose. These cases have been thoroughly tested by Mr. Lyon and myself for insect-proof qualities, and have been found excellent. Their price is already less than that of the ordinary wooden box, and would be further reduced by mass production. It remains to consider two points—labour costs and strength. As regards the former, though it would appear that only the middle strip, top and bottom, can be sealed by machinery, yet, since the use of these boxes would delete entirely from shed procedure the complicated operations of making the wooden cases, inserting the paper lining, nailing on the lid and finally wiring, there would be, probably, rather a saving than an added expense. The question of strength to withstand carriage is much more serious. A small shipment sent by the new Hydro Vacuum Company of Melbourne and examined in London last December showed very great injury by straining, by the impact of other box corners and by the hands of pilferers. This shipment was partially crated ; but neither crates nor complete boxes would be economically practicable, while the former are not even efficient.

A larger shipment consisting of 80 28-lb. and 40 56-lb. boxes of cold-dipped sultanas and 40 56-lb. boxes of hot-dipped sultanas accompanied me on the R.M.S. "Orama." There were also 12 marked "S" and made of much stronger, pure fibre board. These latter cost nearly as much as the corresponding wooden case. The ordinary corrugated cardboard containers used in the bulk of the experiments withstood the journey from Mildura to Melbourne very badly. Even though handled with much greater care than the wooden boxes, they were strained and broken in a variety of ways, as follows :—

(1) Bulging and almost bursting of lower ones in stack.
(2) Giving of the paper seals.
(3) Abrasion of the paper seals.
(4) Dents leading to gashes.
(5) Breaking of corners on impact—even the cloth binding tearing.
(6) Pressing in of top owing to higher boxes resting uneven in the pile.

The pure fibreboard cases, on the other hand, arrived at the wharf in good condition, but it is doubtful whether even these would stand the treatment received by the wooden boxes.

All the cartons were stored in a hold with the standard wooden boxes of dried fruit, and were stacked nine to ten deep, which is certainly all they will endure. In the centre of number one hold, by comparison, the wooden boxes were piled fifty deep. Even at that stage of the experiment it could, I think, be definitely asserted that both the 28 lb. and the 56 lb. boxes made of ordinary corrugated cardboard are not strong enough for the export trade. Sufficient of the pure fibreboard boxes were not obtainable, at the time, to arrange a large enough experiment. They might be tried on a larger scale. It is evident, however, that some form of special stowage will be necessary if any kind of carton container is adopted for the whole export trade. It has been suggested that they should go as " top cargo," at, if necessary, somewhat extra cost, but Mr. Johnson, Manager of the Orient Line in Melbourne, states that there is no regular " top" and " bottom " storage for bulk cargo. He believes that should the industry find it necessary to adopt cartons, the shipping companies will find a way to handle and to stow them without extra cost. This, of course, is not a promise but merely an expression of opinion.

Condition of cartons on arrival in London : of the 80 small boxes, 4 were broken ; of the 80 large, no fewer than 40. Of the 12 stronger fibreboard boxes marked " S " only one, a 56 lb. was actually broken.

All boxes below about five deep in the hold were badly crushed, if not actually burst by the pressure of those above. Even the " S " boxes were nearly all—especially the larger ones—knocked badly out of shape and given a most unsightly appearance.

The consensus of opinion of those who examined the boxes was that such containers are now a demonstrated failure. They were given throughout rather special treatment which could not be expected for a bulk shipment ; they arrived broken, burst, unsightly, and on the whole rather more open to moth infestation than the standard wooden boxes. It is possible that the 28 lb. strong fibreboard containers could be used ; it is perhaps worth while trying them on a larger scale. Further trial of the others is not recommended.

The hot dip fruit had not softened the substance of these unlined card-containers, either the corrugated or fibreboard, to any appreciable extent.

A strong additional argument suggested by Mr. Lyon for insect-proof containers was that, in view of the huge crop in 1927, there would undoubtedly remain a large quantity of fruit unsold till the next year. In this, under present methods, there would be indubitably infestation and deterioration—in insect-proof containers it would be safe. While it was too late to adopt such containers for the 1927 crop there will doubtless be future heavy yields to which the same argument will apply.

(*e*) *Centralisation.*

Under this head are included centralisation both of packing sheds and of storage warehouses. Entomologically such a step would be extremely sound. Not only would it facilitate inspection and supervision, it would also render practicable the adoption of more labour-saving machinery for insect proof packing ; it would tend to standardise such packing ; it would favour preliminary sterilisation where that was necessary ; and finally would reduce the percentage of infestation by a quicker turn-over and a larger output. If centralisation of packing-sheds prove impracticable for financial reasons, it is suggested that the packed fruit ordinarily stored in the packing shed be taken to a central store in each district, this store to be a model one, with all facilities for disinfection and if necessary fumigation.

Centralisation of warehouses, for storing dried fruit in London, is already proceeding.

V. SUMMARY.

1. By far the most important pest of Australian dried grape fruits is *Plodia interpunctella.*

2. Another moth and a beetle are fairly important, but attention should be concentrated on *Plodia* since its elimination would nearly always involve that of the others.

3. The larvae of *Plodia* are neither " grubs " nor " maggots " but more correctly caterpillars.

4. *Plodia* lives on a wide variety of dried food products and is nearly cosmopolitan in distribution.

5. By far the most important factor influencing the duration of the life-cycle in *Plodia* is temperature.

6. The cycle may vary from 31 days in the hottest part of the Australian summer to many months if winter intervene.

7. *Plodia* is essentially now an indoor insect. It spreads but little by its own efforts.

8. There are probably two broods per year in Australia ; but individual variation in development obscures these greatly.

9. Fruit shipped in late autumn or winter and meeting hot weather in the tropics will arrive in London in the same state with regard to " grubs " as that stored in Australia till the end of January.

10. *Ephestia cautella* is common in the raisin districts ; but is attracted chiefly to unpacked fruit, whence it is largely eliminated by the steamer and grader, so that it is almost negligible as a factor in the final London infestation.

11. *Silvanus surinamensis*—a small beetle—is, next to *Plodia,* the most abundant insect in Australian dried fruit, but it infests chiefly fruit which has been previously attacked by *Plodia* and *Ephestia* or has been stored a long time.

12. At least so long as the present cleanliness regulations are enforced, drying-rack infestation by *Plodia* is commercially negligible.

13. *The bulk of the infestation occurs after the fruit is packed.*

14. It is strongly recommended (*a*) that packing sheds be cleared of *all* fruit and thoroughly disinfected before the first cut fruits begin to arrive, and (*b*) that the cut fruits themselves be removed and the sheds again cleaned as soon *before* the 31st January (the present regulation date) as conditions in each district will allow.

15. Dried grape fruits should never be stored in the same warehouses or sheds as the cut fruits of the same season.

16. Until means can be found of altering West Australian procedure so as to obtain a quicker turn-over of fruit, West Australian dried fruit should receive special attention and should not be stowed in the same hold or stored in the same warehouse as Victorian or South Australian fruit.

17. Storage sheds for export dried fruit should be brought under exactly the same hygienic regulations as the packing-sheds themselves.

18. Infestation on shipboard is not likely, save from *Plodia* already present in the fruit ; but hot weather during the voyage greatly accelerates the development of a second brood.

19. Ants of the genus *Iridomyrmex*, and the parasitoid wasp, *Habrobracon*, account for very large numbers of " grubs " but it does not appear practicable to further their efforts artificially.

20. The ordinary stemming and grading machine was found experimentally to eliminate all stages of *Plodia* and of *Ephestia* save the eggs, of which it disposed of about 95 per cent.

21. Where moths still continue plentiful in packing-sheds and warehouses, they may be trapped by means of cold tea exposed in shallow pans ; but preventive measures should receive the greatest attention.

22. If pre-packing sterilisation prove necessary, then a heat method is the most efficient and the most economical.

23. Of fumigants, the one used by Mr. Plumbridge is the most efficient and the cheapest known to me.

24. Owing to the cost of adequate sampling to ascertain infestation, it will be necessary to continue to fumigate all Australian fruit on arrival in England, at least until insect-proof packing is adopted.

25. Since the bulk of the infestation occurs *after* packing, and prevention is better than cure, the logical measure against *Plodia* is insect-proof packing.

26. The most promising type of insect-proof container is a *complete* paper envelope fitting inside the present wooden boxes.

27. Centralisation of packing sheds and of warehouses is strenuously advocated.

VI. BIBLIOGRAPHY.

The present list of citations is not intended as a complete bibliography either of dried fruit insects in general or of *Plodia* in particular. In includes references only to those works which have been useful in the present investigation.

Back, E. A. and Cotton, R. T., 1926.
Biology of the Saw-toothed grain beetle, *Oryzaephilus surinamensis*, Linne.
Journ. Agric. Res., Vol. 33, pp. 435–452, 4 figs., 5 tables.

Casey, D. A., 1924.
Report . . . to the Commissioner for Australia in the U.S.A. Grubs in dried fruits. (Part of report transmitted to the Prime Minister of Australia by Sir James Elder.)

Christie, A. W. and Woodworth, C. E., 1923.
The relation between insect growth and moisture in dried fruits.
Reprint fr. *Western Canner and Packer*, Sept. Sep. pag.

Essig, E. O., 1926.
Insects of Western North America. New York.

Goodwin, W. H., 1922.
Heat for control of cereal insects. *Ohio Agric. Exp. Sta.*, Bull. 354. 18 pp.

Hase, A., 1922.
Biologie der Schlupfwespe *Habrobracon brevicornis* (Braconidae). Wesmael Zugleich ein Beitrag zur Frage der biologischen Bekämpfung von Schadinsekten.
Arb. Biol. Reichsanst. Land-u. Forstw. Bd. 14. (2). pp. 95–118, 33 figs.

Hase, A., 1923.
Weitere Beiträge zur Frage der biologischen Bekämpfung von Schadinsekten, insbesondere über die Bekämpfung der Mehlmotten mit Hilfe von Schlupfwespen.
op. cit., Bd. 12. (2) pp. 51–78.

——, 1925.
Weitere Versuche zur Frage der biologischen Bekämpfung von Mehlmotten mit Hilfe von Schlupfwespen.
op. cit., Bd. 14. (2) pp. 163–169.

Knapp, A. W., 1923.
Insect pests in the cacao store.
Publication Department, Bournville Works, 16 pp., 6 figs.

Lovett, A. L., 1921.
The Indian Meal Moth (*Plodia interpunctella,* Hübn.).
16 *Bienn. Rep. Bd. Hort. State Oregon,* 1921, pp. 118–123, 4 figs.

Lyon, A. V., 1924.
Problems of the viticultural industry.
Commonwealth Austr. Inst. Science & Indus., Melbourne, Bull. 28, 84 pp., 17 figs.
The production of high quality fruit.
Journ. Dep. Agr. S. Australia, Vol. 29, pp. 956–959.

Meyrick, E., 1895.
A *handbook of British Lepidoptera.* London.

Myers, J. G., 1927.
" Grubs " in dried fruit.
Austr. Dried Fruits News, Vol. 2, No. 7, pp. 11–13. (Reprinted from *Murray Pioneer* of 4th March, 1927.)

de Ong, E. R., 1923.
Habrobracon juglandis, Ashmead, as a parasite of *Plodia interpunctella,* Hübn.
Journ. Econ. Entom., Vol. 16, pp. 550–551.

——, 1924.
Dried fruit insects.
(Part of report transmitted to the Prime Minister of Australia by Sir James Elder.)

Parker, W. B., 1915.
Control of dried fruit insects in California.
U.S. Dept. Agric. Bull. 235, 15 pp., 7 pls., 4 figs.

Quayle, H. J., 1926.
The codling moth in walnuts.
Calif. Agric. Exp. Sta., Bull. 402, 33 pp., 11 figs.

Showell, H., 1927.
Dried Fruit Grub.
Australian Dried Fruits News, Vol. 2, No. 7, p. 7.

APPENDIX I.

Matters for Further Investigation.

It has been already stated that the time was insufficient to elucidate several important points.

Further life-history data on *Plodia* and *Ephestia* under Australian conditions are being gathered by Mr. G. F. Hill at Melbourne and by Mr. A. V. Lyon at Mildura (Merbein).

The new Hydro Vacuum Company have promised to arrange an experiment under Mr. G. F. Hill's direction, to ascertain what proportion of *Plodia* eggs is destroyed by their process.

Mr. E. Seary, of the Renmark Co-operative Packing Company, will put into experimental operation his machine for the heat sterilisation of dried fruit, and should be assisted if necessary.

It is highly desirable that a detailed and long-continued study be made of the cycle of insect attack in bulk stored dried fruit. This has never been done.

APPENDIX II.

Wooden Boxes for Dried Fruit.

As of not strictly entomological concern, these few notes on the materials and construction of the wooden boxes used for packing dried fruit have been relegated to an appendix. None of the boxes at present used are insect-proof, but some are far more so than others. By far the best boxes seen were Californian 25 lb. cases shipped to London. These were of sugar-pine, well put together. No Australian containers equal these. Australian timber comes from three main sources : Canadian, North European and local. The first is sometimes better timber than the second, but is more often not cut accurately to size, with the result that in small sheds, which cannot afford to instal machinery for trimming, the boxes are necessarily ill-constructed, with wide gaps and severe strains. The local *Pinus insignis* (*radiata*) is also often very roughly cut. Even when the pieces are cut accurately to size there is far too often a tendency towards slap-dash methods when the boxes are put together, leading to gaps which could easily have been avoided. In some sheds, especially in South Australia, a penny wise, pound foolish policy exists of using nails far too short, and three instead of the regulation four at each end of the sides in 56 lb. boxes. In nearly every case, after a minimum of handling, this results in a gaping at the ends big enough to admit the finger. The most efficient Australian boxes seen were 1,600 from the Swan Settlers' Association of West Australia, shipped on the R.M.S. " Orama." I have not yet been able to ascertain the source of the timber, which appeared, however, to be homegrown since it was only stencilled and not printed.* The pieces were accurately cut, the boxes well constructed with the full complement of nails, while the timber itself was much thicker than that used in the Eastern States. The result was that not one of these boxes appeared to be injured or strained by the handling during stowage, as were such a large proportion of the Victorian and South Australian cases.

APPENDIX III.

The Supposed Immunity of Near Eastern Fruit.

More especially since attention was drawn to the likelihood of considerable infestation by *Plodia* in London, there has been much discussion regarding the supposed immunity of Near Eastern, particularly Smyrna, fruit. In a very wide experience, Mr. W. P. Caro, appraiser to the Australian Dried Fruit Board, has seen no " grubs " in Smyrna dried grape fruit. A round of various brokers and merchants showed that the " trade " fully corroborated Mr. Caro's experience, and there can be no doubt that grubs are almost infinitely rarer in Smyrna fruit than in Australian. There were a few records of " striped grubs," almost certainly *Ephestia* larvae, in such fruit, but these had left the boxes soon after arrival and there had been no further trouble. This tallies well with the Australian evidence that *Ephestia* does not seem to re-infest dried grape fruits after they are packed.

---

* Mr. Geo. W. Wickens, Superintendent of Horticulture, has since informed me that this timber was " Swedish white pine."

But while I have been convinced that *Plodia* is almost infinitely rarer in Eastern than in Australian fruit, I am also of the opinion that the difference lies in those space and time factors in which the Australian product suffers such a disadvantage. Smyrna fruit arrives in England in September, October and November, *i.e.*, after the great risk of English infestation is over, and after the heat which would cause the rapid development of any infestation already in such fruit in the form of eggs or small grubs. Even if such fruit were not only already holding such an initial infestation but were also infested with eggs soon after arrival, I should not expect a commercial infestation to be apparent until July and August. But these two months are the very ones which Smyrna fruit is the least likely to spend in England before consumption.

Contrast this with conditions for Australian fruit. This leaves Australia with or without an initial infestation. At whatever time of the year it makes the voyage its initial infestation (if present) save under unusual conditions, is developed to a second infestation. It begins to reach England in late spring or early summer, and even if clean at the wharf, can receive a considerable infestation from local sources by the end of August before the Smyrna fruit is on the scene. The latter escapes contamination from the Australian boxes because the moths are no longer very active. I was informed of one case where Smyrna fruit was invaded by grubs from adjacent Australian piles. The fruit inside the boxes was thickly coated with their silken webbing, but itself, closely compacted, was entirely unpenetrated and apparently unharmed. This was most emphatically not due to some mysterious immunity, but merely to the fact that the larvae did not leave the Australian fruit until they were full-fed, and were then just looking for places in which to pupate. They would have done exactly the same had the Smyrna fruit been piles of drainpipes instead.

It has been stated, however, that year-old Smyrna fruit is cleaner than Australian fruit of similar age. One merchant had seen year-old Smyrna fruit infested, but he attributed this to " striking " by blowflies from round the corner at Billingsgate. These " blowflies," he said, are especially active in depositing their " maggots " in the fruit in *July and August*. The conclusions are obvious and certainly point to local infestation of Smyrna fruit—by moths and not by blowflies, of course—when it is stored in London during the danger months of July and August.

But there is another factor to be considered in the infestation of old dried fruit. It is quite incorrect to suppose that the older the fruit the more it is liable to infestation by *Plodia*. There are definite indications, which I have not been able to follow as far as I should like, that dried fruit is attacked by a succession of different kinds of insects at different stages of maturity and " sugaring " just as in an animal corpse or a dead log. *Ephestia* for instance prefers fruit which has not yet been packed, *Plodia* that which has been stored some time and *Silvanus* older fruit still. It is thus probable, though not proved, that Smyrna fruit which had arrived too late for an autumn infestation would, if kept till the following July, be neglected by *Plodia* in favour of the new season's Australian fruit.

To clinch the matter finally, I can arrange an experiment, as soon as *Plodia* becomes sufficiently numerous, with Australian and Smyrna sultanas of as nearly as possible similar age and type, to see which the moth prefers. If the Smyrna product is entirely neglected then it will be time to suggest some mysterious immunity factor, and it will be worth while to send an investigator to the East to pursue the matter further.

APPENDIX IV.

Condition of Australian Dried Fruit in the 1927 *Season.*

In Australia I was very favourably impressed with the regulations regarding the cleanliness and the construction of packing sheds, and with the efficient way in which, in the 1927 season for the first time, these rules were being enforced. I felt confident that these measures alone, especially the substitution of concrete for wooden floors, would lead to a greatly reduced infestation that season, and I therefore suggested to the Export Control Board that they refrain from carrying out their intention of fumigating all the fruit as it arrived in London. My suggestion was made firstly in order that the effects of the Australian cleaning-up campaign might not be obscured, and secondly that considerable expense might be saved. But neither the Australian members of the Board nor myself realised the cost of the representative sampling which fumigation of infested shipments only would entail. This practically renders it necessary to fumigate all the fruit in order to ensure that no infestation is allowed to pass and wholesale fumigation is therefore still in force.

To save the experimental results as far as possible, the authorities in London, under instructions from Mr. F. L. McDougall, retained sample boxes of all shipments received before my arrival in England. Approximately half these boxes were securely sealed and the others left just as received; both lots being stored in the usual warehouses, without fumigation, until I could examine them.

The examination was carried out on 17th June, with the following results:—

Of the 46 sealed and 48 unsealed boxes, 80 were free from insect life. The particulars regarding the other 14 are given in detail.

(1) One half case, unsealed, sultanas, Aurora Pkg. Co., arrived 11th June. Numerous *Silvanus*, apparently a primary infestation; chiefly adults, but three larvae, no signs of *Plodia*.
(2) One half case, unsealed, currants, Padlock, Mildura. Arrived 27th April. One full-grown *Ephestia* larva.
(3) One half case, sealed, sultanas, Renmark Ark. Arrived 27th May. One adult *Ptinus* sp.
(4) One half case, unsealed, sultanas, Renmark Ark. Arrived 27th May. One full-grown *Ephestia* larva.
(5) One half case, unsealed, sultanas, Renmark Ark. Arrived 27th May. One full-grown *Ephestia* larva.
(6) One half case, sealed, sultanas, Mildura Padlock. Arrived 27th May. One two-thirds grown *Ephestia* larva.
(7) One half case, sealed, sultanas, Renmark Ark. Arrived 27th May. Two adult *Silvanus*.
(8) One half case, unsealed, sultanas. Red Cliffs, O.S.A. Arrived 27th April. One *Calandra granaria*, two *Ptinus* sp.
(9) One half case, sealed, currants, Gollin & Co., Irymple. Arrived 27th April. Four full-grown *Plodia* larvae.
(10) One half case, sealed, sultanas, EF/L Cadell. Arrived 27th April. Two full-grown *Plodia* larvae.
(11) One half case, sealed sultanas. G. J. Dix. Arrived 7th May. Two full-grown *Ephestia* larvae.
(12) One half case, sealed, sultanas, Gollin & Co., Barmera. Arrived 13th May. One *Tribolium* sp. (crushed).
(13) One half case, sealed, sultanas, Bonney. Arrived 11th June. Ten *Ephestia* larvae, all sizes.
(14) One half case, unsealed, sultanas, G. J. Dix. Arrived 11th June. Two full-grown *Plodia* larvae.

Cases (2), (4), (5), (6), (11) where one or two well-grown *Ephestia* larvae were present in each box, are evidently some of those rare instances in which an *Ephestia* egg passes through the stemmer and grader uninjured. I should regard it as extremely improbable that any of these could serve as the basis of a second or commercial infestation. Case (13) is peculiar in that the *Ephestia* larvae were of various sizes. Further information on this box would be useful as the infestation is difficult to explain on our present knowledge. I strongly suspect some departure from the usual shed practice in the place of origin of this box. No. (1) is also a very unusual case, and remains the only instance I have seen of primary infestation by *Silvanus*. Cases (3), (7), (8), (12), involving the presence of one or two adults of various beetles, can be fairly dismissed as largely accidental, and in any case as quite clean commercially. There remain three cases of infestation by *Plodia*, and this in very small numbers. (I may say that all the sealed boxes were completely emptied and the caked fruit broken down) There was thus an infestation of Australian dried fruit by *Plodia*, so far that season, of 3·2 per cent., and of "grubs," including *Ephestia*, of 9·6 per cent. It must be emphasised that these percentages concern fruit as it arrived, without fumigation. If it be suggested that I may have missed eggs in this examination, that is of course possible; but after Australian experience it is impossible that I should have missed all, had there been enough present for a commercial infestation; and it is moreover almost impossible that eggs should come through the tropics without hatching and further development to considerable size. I am therefore persuaded that the 80 cases considered clean, would remain so indefinitely provided only that they were secured by sealing from English infestation.

Now brokers and merchants seemed generally agreed that Australian fruit was much cleaner that season, so far, and *they attributed this entirely to the wholesale fumigation*. But after the above examination, in which most of the few infested cases would have been passed by a non-entomological sampler as clean, and after my Australian experience, *I attribute it almost entirely to the cleaning-up campaign carried out in Australia*. It is probable, of course, that the percentage of infestation would increase as the season advanced, if only owing to contamination at infested warehouses at the ports of export, especially Port Adelaide. None of the above remarks apply to Western Australian produce.

E.M.B.13.

GRAPEFRUIT CULTURE IN THE BRITISH WEST INDIES AND BRITISH HONDURAS

By Professor H. CLARK POWELL, B.Sc.,

Professor of Horticulture, Transvaal University College, Pretoria.

DECEMBER, 1928

LONDON:

PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE

To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller.

1928.

Price 1*s.* 0*d.* Net.

70–221–13.

CONTENTS.

(34437) Wt.P1764/494/1218 2,500 12/28 Harrow G.3

PREFACE.

On receipt of applications from certain Colonies for financial assistance in developing citrus fruit cultivation and export, the Empire Marketing Board felt the need for a general review of the prospects of citrus production in the Colonial Empire. The cultivation of oranges and grapefruit in the Empire was seen to present many problems alike of horticulture, of transport, and of marketing, and the Board decided to arrange for a citrus specialist to pay a visit to the principal fruit exporting countries of the Colonial Empire to advise as to their methods of cultivation and marketing, and to guide the Board in considering applications for grants.

Accordingly, in August, 1927, the Board invited Professor H. Clark Powell, Professor of Horticulture at the Transvaal University College, Pretoria, and Technical Adviser to the South African Co-operative Citrus Exchange, to investigate the problems relating to citrus fruit cultivation in various Empire countries.

With the concurrence of the Transvaal University College and the South African Co-operative Citrus Exchange, Professor Clark Powell was fortunately able to accept the Board's invitation, and in view of the value of the proposed tour to South African Citrus Growers, the South African Co-operative Citrus Exchange generously contributed £200 towards the expenses of his journey, the balance being provided by a grant from the Empire Marketing Fund.

He first visited Palestine, Cyprus and Zanzibar and submitted Reports to the Governments concerned and to the Board.

The survey which follows deals with grapefruit culture in the West Indies and British Honduras, and contains, in addition, notes on the various Colonies visited. It was also arranged for Professor Clark Powell to visit and study for comparative purposes the citrus-growing districts of California and Florida. He has furnished to each Colonial Government and to the Board more detailed reports on the results of his investigations.

It may be anticipated that the report, envisaging as it does the possibilities of the establishment of a remunerative grapefruit industry, will be received with satisfaction in the West Indies. It should give encouragement especially to those Colonies in which a new industry is urgently needed to provide an alternative to a languishing staple crop ; but to all it should provide an additional opportunity for economic development whereby they may be able to contribute towards meeting the growing demand in this country for fruit produced within the Empire.

EDWARD DAVSON,
Chairman of Colonial Fruit Grants Committee.

Empire Marketing Board.
November, 1928.

GRAPEFRUIT CULTURE IN THE BRITISH WEST INDIES AND BRITISH HONDURAS.

Introduction.

NATURAL conditions of climate and soil are more favourable in the West Indies for grapefruit growing than in any of the countries in which the bulk of the grapefruit of the world is produced. California, Arizona, Texas and Florida are handicapped by unfavourable factors such as low rainfall, high-priced land, the need for extensive fumigation or spraying and expensive soil fertilization. The rainfall in the West Indies is sufficiently high to eliminate any necessity for irrigation ; the soil is very fertile and its fertility can be maintained in a much cheaper manner than in any of the areas mentioned. Abundant land can be purchased at a low cost. Pest control is more economical than in semi-arid countries. As a result of these most favourable natural conditions, grapefruit can be produced in the West Indies at a very low cost.

During the past few years the world's production of grapefruit has increased rapidly and a greater increase will come in the next few years, as can be seen by reference to Table 1. Through a consideration of these figures alone, it would seem unwise to carry out any further expansion of grapefruit production but with these figures should be considered the factor of production costs and delivered cost in the consuming markets. The bulk of the world's grapefruit supply is produced in the United States and it is in this country that production costs are highest. A marked increase in production is taking place in the United States which will result in increased exports to the United Kingdom. The markets for the West Indies are the United Kingdom and Canada and in both of these markets West Indian grapefruit can be landed and sold at a lower cost than grapefruit from the United States.

TABLE 1.

Grapefruit Acreage in Various Producing Areas.

Area.	*Bearing.*	*Non-bearing.*	*Total Acreage.*
Florida . . .	60,651	19,610	80,261
California . . .	5,417	4,187	9,604
Texas	7,000	35,000	42,000
Arizona . . .	1,200	900	2,100
Isle of Pines . . .	10,270	2,900	13,170
Porto Rico . . .	3,145	615	3,760
Total . .	87,683	63,212	150,895

(Figures from Florida Citrus Exchange Statistical Bulletin, 1926–27.)

California, Arizona and Texas cannot land and sell grapefruit in the United Kingdom markets for less than 18*s*. a box. Their costs in the eastern Canadian markets are approximately 16*s*. a box. Florida, the Isle of Pines and Porto Rico cannot land and sell their grapefruit in the United Kingdom for less than 15*s*. to 16*s*. a box, and in Canada their delivered costs are about 14*s*. a box.

The following figures are considered to be representative of general costs throughout the West Indies :—

	Per Box. *s.*	*d.*
Cost of production	1	6
Picking, transport, packing	4	6
Freight to London	4	0
London charges and commission . . .	3	6
Total . .	13	6

The landed cost of West Indian grapefruit in the eastern Canadian markets is slightly less than in London. Further, in Canada the West Indian grapefruit has the advantage of a tariff of one cent (1c.) per pound that is levied against American grapefruit.

Therefore, in spite of the large increase in American grapefruit production that is taking place (87,683 bearing acres and 63,212 acres yet to come into bearing) the West Indian producer has a marked

advantage in his lower delivered cost both in the United Kingdom and in Canada. In the event of over-production, the country that has fruit of good quality, well-packed and marketed properly and that can sell at a lower price than its competitors, is fully justified in continuing or expanding its production.

While, however, the West Indies and British Honduras can land and sell fruit in England at a lower cost than the chief citrus fruit producing countries, it must not be assumed that this fact alone will enable the West Indies or British Honduras to establish a fruit industry. With grapefruit in particular, the well-known brands from Florida, such as Sealdsweet and Blue Goose, have become well-established with the English public and because of their quality and uniformity will always find a market. They must be sold at a higher price than the fruit from the West Indies but unless the West Indies and British Honduras can ship fruit equal to them in every respect, the public will continue to demand the higher priced fruit. Low costs of production and marketing when combined with very careful grading and packing, high quality and sound condition on arrival, will enable the West Indian producers to market an ever-increasing quantity of grapefruit.

Jamaica, Trinidad and British Honduras are at present the chief centres of production of grapefruit in the West Indies, and as the industry in the two latter places is in its infancy, the importance of the initial steps for development can hardly be over-emphasized. Co-operative packing, careful grading, uniformity of product and careful handling should be given continual thought and attention.

The grapefruit is a comparatively new article of commerce. Its uses and consumption have not yet been stabilized. Even in the United States where the annual supply is in the vicinity of 10,000,000 boxes, consumption is increasing rapidly. The grapefruit has gained a place of distinction as a breakfast fruit, as a salad fruit, and grapefruit juice is becoming increasingly popular. A remarkable increase in consumption of grapefruit is occurring in Great Britain, as can be seen from Table 2. It is impossible to estimate the extent to which this increase will go but there is every indication that it will continue for some years. A study of the monthly import figures shows that grapefruit consumption in England is no longer seasonal with the tourist traffic.

Table 2.

*Imports of Grapefruit into the United Kingdom in boxes.**

Year.	South Africa.	British West Indies.	Other British Countries.	U.S.A.	Other Foreign Countries.	Total.
1921 . .	2,440	8,770	254	17,923	4,931	34,318
1922 . .	10,216	8,854	—	30,689	800	50,559
1923 . .	12,509	16,877	1,170	45,105	4,418	80,238
1924 . .	15,768	15,787	925	93,689	4,018	130,186
1925 . .	21,837	28,171	784	200,071	17,353	268,186
1926 . .	20,997	43,486	2,688	239,847	25,939	332,956
1927 . .	23,907	47,493	8,926	501,314	24,829	606,468

The various West Indian islands, notably Jamaica, Trinidad, St. Lucia, Dominica and Grenada, are showing a keen interest in developing or expanding their grapefruit industries. Successful realization of their efforts depends on the producers having adequate knowledge of such factors as soils, sites, nursery work, planting, fertilizers, the care of young groves, the care of bearing groves, picking, grading and packing. Many publications have been issued and several books have been written on citrus fruit culture and its many phases. These publications, excellent as many of them are, have been based for the most part on the factors surrounding orange production under conditions that are totally different to those obtaining in the West Indies. Reference to them for such points as soils, soil fertility, irrigation, fumigation, frost protection or marketing is useless for the West Indian planter. The arid conditions of the southwestern United States (Texas, Arizona and southern California), where the annual rainfall is from 5 inches to 35 inches per year are totally different to the conditions in the West Indies, where the rainfall varies from 50 inches to 250 inches per year. The soils of Florida are characterized by their sandy nature and deficiency in plant food ; West Indian soils are typically heavy in texture and extremely rich in plant food and organic matter.

Under such remarkably varying conditions, the factors of production are found to vary just as greatly. The use of publications from Florida or California is, therefore, unwise, as the conclusions therein can easily be misunderstood. This paper is written in an attempt to set down some of the writer's conclusions

* Adapted from Empire Marketing Board Fruit Intelligence Notes, Feb. 22, 1928, on the basis of 70 lbs. per box.

and observations gained during a study of citrus fruit conditions in the West Indies. As the remarks are based solely on observation, it must be considered that they are not final. Experimental work and further experience of the planters and local Departments of Agriculture will no doubt result in some modification of the points given herewith. However, until further evidence is available, it is hoped that this paper will prove of some value to the countries of which it treats, namely, Trinidad, Dominica, St. Lucia and Grenada. The general remarks apply equally as well to Jamaica and to British Honduras.

Soils—Rainfall—Site.

The best soils for grapefruit are deep, medium-textured loams that are fertile and well-drained. There is an abundance of such soil in the West Indies. In British Honduras the alluvial loams of the Stann Creek Valley can be mentioned as examples of excellent soil. In the same country, the soils along the lower reaches of the Sibun and Belize rivers can be noted as examples of undesirable soils. They are too heavy, too shallow and too poorly drained to justify their use for any commercial planting of grapefruit.

In Trinidad, as examples of good soil, can be mentioned the site of the Agostini grove near the Pitch Lake and the alluvial soils in some of the valleys east of Port-of-Spain. Sandy soils, such as are found near Siparia, will produce abundant fruit crops, but to do so they require constant fertilization and their use should be deferred until the better soils have been utilized.

Dominica possesses a great abundance of suitable soil. The Fond Hunt lands near Portsmouth, the Layau Valley and many other areas are extremely suitable for grapefruit growing.

Florida soils are very sandy, many of them being practically all sand, and because of their light nature and deficiency in plant food, the Florida growers must use 60 to 90 pounds of commercial fertilizers per tree per year. If West Indian growers plant on soils requiring such heavy fertilization, they immediately lose their advantage of low production costs.

Heavy clay soils should be avoided because on such soils "gummosis" is serious. This disease should not be troublesome on medium soils that are well drained, if trees are budded 10 inches high on sour orange root stocks.

Shallow soils, underlain at 18 inches or less with an impervious subsoil or rock, are not adapted to successful citrus fruit production. Such soils do not permit maximum root development and are very liable to become water-logged. The presence in the soil of free water is injurious and will eventually result in the death of the trees through actual death of the feeding roots or through the development of mal di gomma (syn. collar rot, foot rot, root rot).

Therefore, a prospective planter should choose a medium soil, fertile, well-drained and at least 24 inches deep.

The question of annual rainfall must be considered. In the greater part of the West Indies, the rainfall is abundant and well distributed throughout the year. Areas having 50 inches of rain or less should be avoided. Grapefruit trees can bear good crops with 50 inches of rain per year if it is well distributed throughout the year. Under such conditions, however, the entomogenous fungi that attack the scale insects are unable to thrive and scale insects may cause severe damage to the trees. Spraying can be employed as a means of scale control but as the areas of higher rainfall are so abundant it would not seem wise to plant in districts where artificial means of scale control are necessary.

Further, in areas with an average rainfall of 50 inches, there will normally be years when the rainfall is considerably less, and in such years the trees will suffer from drought.

Rainfall of at least 75 inches is highly desirable and it should be well distributed throughout the year. During dry periods scale insects multiply rapidly and if these dry periods are of three or four months duration every year, scale may increase to such an extent as to become very injurious.

As to the safe maximum rainfall, little can be said. The writer saw grapefruit plantings in the interior highlands of Dominica under an annual rainfall of 200 to 250 inches and they were in excellent condition and bearing large quantities of clean fruit. As an example of successful grapefruit culture in a high rainfall area can be mentioned the planting of Messrs. Rossi and Rolle in Dominica. Their planting of several acres is at an elevation of 1,500 feet, with an annual rainfall of about 250 inches, yet the trees are in excellent condition in every respect.

With very heavy rainfall, however, grove costs are increased somewhat because of the necessity for providing an extensive system of surface drainage. The number of drains will naturally vary with the amount of rainfall and the slope of the land. In extreme cases, three or four main drains (about 18 inches wide by 18 inches deep) will be necessary per acre. Lateral drains (12 inches wide and 12 inches deep), feeding the main drains where possible, will be necessary between every second or third row. These drains must be cleaned whenever the land is cutlassed. The higher the rainfall, the more surface drains required ; the more surface drains, the higher the annual costs. Generally speaking, a rainfall of 75 inches to 100 inches will be found most satisfactory and economical.

The site for the planting should be chosen with due regard to the soil and rainfall conditions mentioned and factors of health conditions, social environment, transportation and slope of the land must also be considered. Proximity to a town may be deemed an advantage by some. In any case, proximity to planters having similar interests is a valuable asset to any individual. Social intercourse is one of the most important elements in one's life. Further, location in an area where there are citrus fruit growers leads to an exchange of thought and experience that can prove most valuable.

As grapefruit is a perishable article, any mechanical injury to it during transit from the grove to the consumer will result in decay. Good roads are a factor minimizing the injury that can take place from the grove to the point of export, hence location on a good road is a distinct asset. Trinidad is extremely fortunate in having an excellent road system.

A site for grapefruit planting that has a very steep slope should be avoided because of the fact that all grove operations, and particularly picking, must be carried out under difficulties. When picking is carried out under difficulties of any kind the handling of the fruit is very liable to be rough. Land with a steep slope will suffer from washing unless an extensive system of surface drains is provided. The prospective planter should choose land with a moderate slope. Flat land is very liable to be poorly drained but in the event that it is well drained, it is desirable.

A site that is exposed to strong winds should be protected by the planting of a suitable windbreak. In some of the islands " pois doux " has proved to be an excellent windbreak.

Planting the Grove.

Before the young grapefruit trees are planted, the land should be cleared of all natural vegetation. The cost of this clearing will vary from £3 an acre on land with little natural growth to about £8 on land that is heavily forested. The planting of young citrus fruit trees "under shade" is most undesirable as shade from cacao or other trees is injurious. The presence of non-citrus trees in the planting will cause upright growth of the young citrus trees that are shaded and delay their bearing period materially.

After clearing, it is necessary to fork up the actual spots where trees are to be planted. The digging up of a small area six feet or more in diameter is sufficient. Ploughing of the entire grove is probably unnecessary under West Indian conditions.

Surface drains are required in all areas subject to heavy rainfall. Drains should be made before the trees are planted and should be of such a number and depth as the rainfall, the character of the subsoil and the slope of the land indicate. No rule can be laid down in regard to the provision of surface drains as the problem is one peculiar to each individual grove.

The planting of a cover crop the year before planting and its subsequent ploughing under is not necessary as the soils in the areas under discussion are characterized by their high content of organic matter.

The square system of planting is the most satisfactory and is recommended. Contour planting is recommended in semi-arid countries where groves are set on a hillside, because by so planting, irrigation furrows can be run at an even, gentle gradient. Irrigation is not necessary in the West Indies, hence the square system of planting can be followed on flat and sloping land alike.

A planting distance of 30 feet by 30 feet will probably be found the most satisfactory. Even at this distance it will be found that in twenty or twenty-five years the trees will cover practically all of the available ground.

The use of "fillers," or trees set between those at thirty-foot intervals, is not recommended. Although the grower may fully intend to take the extra trees out when they begin to crowd the permanent trees, in actual practice he rarely ever does so at the time when it is necessary. If the fillers are bearing well, the

inclination is to leave them for a while longer; if they have not borne well, the tendency is to leave them a while longer and make them bear. Plant the trees 30 feet by 30 feet and do not attempt the use of fillers.

Various inter-crops can be grown successfully in a grove during the years before the trees come into production. An inter-crop should be an annual, the growth habit of which is not of such a nature as will interfere with the development of the trees. It should be planted in the centres of the rows only, leaving a clear space of at least 6 feet on each side of the trees. As the trees become older and larger, this space must be increased. At no time should the presence of an inter-crop be allowed to interfere with the trees. Care should be taken to see that, through the use of an inter-crop, the organic content of the soil is not diminished. It must always be remembered that the trees are the permanent and most valuable crop and their welfare must not be imperiled in any way. If the inter-crop is sufficiently profitable, cut the trees out and use the entire land for such a crop. At the end of four or five years, inter-cropping should be stopped.

The actual laying out of a grove is purely a mechanical operation and the procedure varies with the outline of the grove to be planted. Square or rectilinear plantings present no problems but irregular groves are somewhat more difficult. For the actual details of measurement, refer to books such as Wickson's "California Fruits," Coit's "Citrus Fruits," or Hume's "The Cultivation of Citrus Fruits."

A planting distance of 25 by 25 feet will give 70 trees to the acre; 30 by 30 feet gives 48 trees per acre.

Grapefruit trees can be planted at any time of the year provided no prolonged dry period is anticipated. Planting at the beginning of the dry period is not desirable because of the set-back that is given to the young trees during the dry weather. The root system has not yet become established and any drying out of the soil is injurious.

When the exact spot on which each tree is to be planted has been determined, the planting holes can be dug. It is not necessary to dig a large hole; the hole should be large enough to accommodate the roots of the nursery tree without cramping. The depth is

optional. If a hard subsoil is present it is well to extend the hole into it, placing rich top-soil in the bottom of the hole before planting the trees. Holes dug from 12 inches to 18 inches deep and from 12 inches to 18 inches in width are large enough.

No manure or organic matter should be placed in the hole. If a poor soil is being used and fertilizers are considered necessary, they should be strewn on the ground after the trees are planted. Manure or organic matter in the hole itself will result in subsequent sinking of the little trees.

Should a grower feel it necessary to plant on clay soil or on poorly drained soil, it is advisable that the trees be set on mounds about 6 feet square and 2 feet high or on ridges 6 feet wide

FIGURE 1.—A five year old grove in Trinidad, showing deep surface drains. The rainfall on this site averages 110 inches per year and the soil is heavy.

and 2 feet high running the length of each row. Such mounds or ridges should be made some months before the trees are planted in order that they may become compact and firm before the trees are set out.

When the planting holes have been dug, the nursery trees should be brought into the field, a few at a time as needed. It should be remembered that citrus trees do not live because of transplanting but *in spite* of it. They must be handled carefully and should not be allowed to dry out. The roots should be covered with wet sacking or grass. Any broken or injured roots should be cut away back of the injured point.

In placing the nursery tree in the planting hole, care should be taken to avoid any bending or cramping of the roots. When a tree is pushed into loose soil, the roots will bend, hence the trees should be *placed* in the holes.

One of the chief causes of gummosis is deep planting. The young nursery tree should be planted as high as possible. If the crown roots are just showing, the planting has been well done. Trees are rarely lost through excessively high planting ; many are lost through deep planting.

As soon as the trees have been planted they should be given water unless the planting is carried out during very wet weather. Whitewashing of the trunks or the use of wrappings of grass or newspaper will prevent injury from sunburn and is recommended during the first year. It is quite possible that a grass or paper wrapping may furnish harbour and protection for some insect pest but the writer is not certain about this point. Advice should be sought from the local Department of Agriculture.

Bud Selection.

Growers realize fully that there are many kinds of grapefruit, each type possessing certain more or less marked characteristics. The present varieties, such as Marsh, Duncan, Walters, are each supposed to represent a type of grapefruit of certain characteristics. It is not fully realized, however, that our present varieties are each composed of *several* types of fruit, some good and some bad. For example, in the Marsh variety, which is supposed to be seedless, there can be found trees producing seeded fruits or pyriform fruits. Similar variations within the variety can be found with all varieties of citrus fruits. Variation in bearing ability is not as common as variation in physical characters of the tree or fruit but it does occur.

A grower who possesses a grove of Marsh grapefruit, for example, with a certain percentage of the trees differing from the desired standard type, is operating the grove under a handicap. Should a large proportion of the trees produce undesirable fruit (of poor flavour or shape) the grower is operating under a serious handicap. Even though a grove of a single variety should contain differing types and all be commercially good, uniformity of grading is impossible of achievement.

It is obvious, therefore, that a grower or nurseryman should select his parent trees with great care in order to be certain that they produce fruit of the desired type and in abundance. From a good parent tree can be propagated trees possessing the same characteristics ; from a poor parent tree will be propagated trees of the same poor characteristics. The asexually propagated descendents of a tree possess the same characteristics as the parent tree from which they are propagated.

In order that suitable parent trees for the purpose of propagation may be selected, the best trees in a mature grove should be studied and records should be kept of the quantity and quality of the fruit borne by each. In this way, after three or four years, the grower or nurseryman can determine the number and location of his best trees and use them for budwood.

The cutting of budwood from a grove, giving no attention to the character of the trees from which the buds are taken, should be severely condemned. In every grove are varying numbers of trees producing undesirable fruit ; the cutting of buds from such trees increases the number of the poor trees in existence and thereby lowers the quality and uniformity of the fruit produced by the country concerned, aside from the serious results to the individual who plants the poor trees.

Variation in quantity of fruit produced is very common but is usually due to variation in environmental factors. Inherent variation in yield ability does occur but is by no means as common as differences in the physical characteristics of the trees and fruit.

Select parent trees with the greatest care, being sure that they bear fruit in abundance and that the fruit is of the desired type in every respect.

Variation occurs not only between the trees of a given variety itself but in the physical make-up of a single tree. In other words, a single branch on a tree may bear fruit differing from the rest of the tree. Propagation of trees from such a branch will result in continuance of the variation (syn. bud sport, bud mutation, off-type). The grower or nurseryman should not only ascertain that his parent trees produce the desired fruit but that *all* of the fruit produced by them is uniformly of the desired type.

As bud variation or mutation occurs from time to time, it is unsafe to take budwood from young trees, even though they may have been budded from good parent trees. The chances are that a young tree so propagated will be true to the characters of its parent but the grower cannot afford to take any risk and should plant trees budded solely from bearing trees of a good type.

Through careful bud selection, the number of poor trees in a grove can be reduced to a minimum and variability of the ultimate product can be avoided.

Root Stock Selection.

Different species of root stocks have different effects on the scion (the portion of the tree above the bud union). Seedling plants of any given species are variable, differing in fruiting ability, type of fruit, leaf and branching characters or type of root development. These physical differences are very marked and it is to be expected that seedling root stocks will also differ in their effect on the scion.

Variation in size, shape, fruiting ability and nature of citrus trees is due to three factors: bud variation, environmental factors such as soil and moisture, and differing effects of the root stocks. The factor of permanent size difference is more clearly understood than any other, with a given stock, and is the one with which the grower is most concerned.

If sour orange stocks are grown to the age of a few months or more, it will be found that although they are of equal age, their size will vary. Some variation in size is undoubtedly due to unfavourable environment affecting certain plants, to insect injury, to a deformed root system or similar factors of a physical nature. Size differences of this nature cannot be expected to be permanent. However, there is a marked variation in size that is due to an inherent difference in rate of growth. Under similar physical conditions, one seedling will reach a size in a given time of 18 inches and another in the same time will grow only to 12 inches. Size differences of this nature are permanent; the stocks will always retain their *relative* size. The difference in rate of growth is transmitted to the scion and a tree budded on a slow growing stock will always be smaller, at the same age, than one budded on a more rapidly growing stock. The tree on the slow growing stock may be healthy in every respect and very productive but, because of its relatively smaller size, it can never

be as productive, under similar conditions, as the tree that was budded at the same time on the more rapidly growing stock.

Reference to Figs. 2 and 3 illustrates this point.

The trees are of the same age, are under similar environmental conditions and have been treated exactly the same throughout their life. Both are representative of approximately 10-acre groves, which are adjacent to each other. The best grove, composed of the large trees, was undoubtedly planted with large, vigorously-growing nursery trees, probably the first to be taken from a block of nursery trees. The first trees to be taken from such a block would naturally be the largest. The second grove was undoubtedly planted with nursery trees that were toward the last of those removed from a block. The

FIGURE 2.—Grove X, Strathmore, California.

FIGURE 3.—Grove Y, Strathmoie, California.

last trees to be taken from such a block would naturally be those of a slower growing type that would take a few months longer to reach the desired size.

The difference in size of the original trees has remained and become more pronounced as the trees matured. The trees in Grove X cost 90c. each ; those in Grove Y were sold at 75c. in competition with the nursery from which the others came and were represented to be just as good as the others. Both groves are healthy and productive. The grove represented by Fig. 2 is more than twice as productive as the other because the trees are larger and can carry more fruit.

The application of this principle of permanent size differences in citrus trees is simple but of the greatest importance to the grove owner. When the young seedlings are transplanted from the seedbed to nursery rows, all relatively small ones and all with deformed roots should be destroyed. When the seedlings have reached budding size, only the largest should be budded and all small ones should be destroyed. The small ones will reach budding size if grown longer but they will never reach the same size as the larger ones because they are relatively slower growing.

When the budded trees are ready for sale or planting, all small ones should be destroyed. The number that will be eliminated at this stage will not be large, not over 5 per cent. to 10 per cent., if the culling in the preceding stages has been severe.

The result of this destruction of inferior plants will be the planting of trees of a very uniform and vigorous growth rate that will develop into large trees in the field. In the grove will be no under-sized, poorly productive trees that are inferior because of the character of the individual stock on which they are budded.

Nursery Practice—Purchase of Trees.

Upon the character of the nursery tree, depends to a large extent the character and productivity of the bearing tree. A good nursery tree can, of course, be planted under unsuitable conditions or managed poorly and hence give unsatisfactory results. A poor nursery tree cannot give good results even with suitable environment and treatment.

The best root stock for the West Indies, as far as one can say at present, is the Seville or sour orange. The sweet orange is susceptible to gummosis and hence is not as good as the sour orange in the countries under discussion. The rough lemon and the lime are also somewhat susceptible to root diseases and should not be used on a commercial scale. The grapefruit, the shaddock, or *Citrus hystrix* may prove satisfactory but evidence in support of this will not be forthcoming for many years. Commercial plantings should be confined to the sour orange root stock and other stocks should be used purely in an experimental way.

If several growers were to plant a dozen trees on several stocks, purely for trial, much practical information would be gained as to the good and bad points of stocks other than the sour orange.

The seedbed should be well drained and of medium to light soil. Heavy soil may restrict root development and favours the development of "damping-off." The seedbed can be made to cover any area desired but for convenience in weeding and caring for the little seedlings it is well to lay it out in belts or strips about 4 feet wide. The length of these beds is immaterial. It is advisable, under the heavy rainfall conditions in the West Indies, to have the beds raised about 9 to 12 inches. Between each four-foot bed should be left a path 18 inches to 24 inches wide. The soil should be dug up to a depth of at least 12 inches and preferably 18 inches. It should be finely pulverized and levelled.

Seed should be obtained from healthy, vigorous, well-grown trees, preferably old ones, and if possible should all be obtained from one tree for the sake of uniformity. Seedlings from different trees probably have different growth rates and may differ in other characteristics as well. The seed should be planted as soon as possible after its removal from the fruit as any drying out before planting will favour the development of crooked roots, the most pronounced type of which is termed "bench root." The fruit can be cut with a sharp knife, cutting only part way through it in order that none of the seeds may be injured. The two halves are twisted apart and the seeds worked out with the fingers into a container. Several washings with water will remove the rag adhering to the seed and facilitate sowing. Should the seed become dry, through unavoidable circumstances, it should be soaked for 24 hours before planting.

The seed can be broadcast in the seedbeds or sown in rows about 6 inches apart, the seed being set 1 inch apart in the rows. A strip of narrow wood pressed lightly into the prepared seed bed will form a very shallow furrow in which the seeds can be placed. The seeds should have some soil raked or scraped over them and then about three-quarters of an inch of sand should be sifted over the entire seedbed.

A fungous disease, "damping-off," is frequently troublesome when the seedlings are young. It attacks the little seedlings at the surface of the ground and the frail stems collapse at the point of attack and the seedling dies. Its progress through a seedbed can be very rapid, a matter in many cases of one or two days. It can usually be avoided by providing adequate drainage (as with the raised seedbed), by allowing the surface of the soil to dry out quickly (hence

the sand mentioned above and the advisability of applying water in the mornings rather than in the afternoons), by avoiding heavy soils and by keeping the soil reasonably free from organic matter, and by an occasional spraying with Bordeaux mixture. If the disease is troublesome, seek the advice of the local Department of Agriculture.

The seedbed should be kept fairly moist but excessive watering is harmful. Facilities for irrigation or watering should be provided as the dry period of the year may affect the small seedlings adversely. The writer saw several nurseries in Trinidad, during a period of dry weather, that were suffering severely because of a lack of water. With small nurseries, ordinary sprinkling is satisfactory, but on a large scale, furrows should be made between each row and water run in them when necessary. The interval between waterings varies with the texture of the soil, wind, temperature, frequency and quantity of rainfall, and other factors, hence no set period can be mentioned.

The seedbed should be kept free from weeds and insect pests.

When the seedlings are about 6 inches to 8 inches high they can be transplanted to the nursery. The seedbed should be thoroughly soaked and each row of seedlings should be forked up, thus allowing them to be removed without injury to the roots. It is of the utmost importance that all small, weak, diseased seedlings and those with deformed roots should be destroyed. Probably 50 per cent. of the seedlings will fall within this category and with possible additional losses from " damping-off," about treble the required number of seedlings should be planted. The tiny seedlings are of little value as individuals and heavy culling of them at this early stage is inexpensive, although of great importance.

The nursery site should be of medium to light soil, at least 18 inches deep, well drained and level. It should not be exposed to strong winds. It should be cultivated deeply, well tilled and free from weeds.

The seedlings are taken from the seedbed and the tops are trimmed and the tap root is cut back for a few inches. Whether the cutting back of the tops for two or three inches in necessary in the West Indies or not, the writer is unable to say. It is suggested that when a large number of seedlings are being shifted, half be cut back and half be untouched and the results compared. After removal from the seedbed, the seedlings should be placed immediately in wet

sacking to prevent any drying out. They are planted in nursery rows about 4 feet apart, being set 12 inches to 15 inches apart in the rows. The soil should be moist before the seedlings are planted and should be given an additional watering immediately after they are planted. This is best done by running water in furrows along each row and is required only when the soil is not sufficiently moist from the natural rainfall. The planting is done with a dibble or trowel and great care should be taken to see that the seedlings are not pushed into the ground in such a way as to cause any bending of the tap root. A bend caused at this time causes permanent deformation of the root system.

The nursery should be kept free from weeds, insect pests and diseases. Should verrucosis (scab) develop, it can be controlled by spraying with Bordeaux, 4–4–50. The plants should be watered when necessary.

During the period when the stocks are growing to budding size, all side shoots should be rubbed off whenever they appear. This ensures a straight stem and hastens the time when budding can be done.

Budding can be done at any time the bark slips, when the stocks have reached a diameter of three-eighths to one-half inch at the height at which the bud is to be inserted. Under the conditions of heavy rainfall and heavy soils so typical of the West Indies as a whole, and the resulting danger from collar rot, budding should be done at least 10 inches from the ground. This is higher than is practised in other countries but it must be remembered that in California, Florida or South Africa the rainfall is much lower and the soils are generally lighter than in the West Indies. High budding greatly reduces the danger from collar rot, not only by keeping the susceptible grapefruit wood away from the ground level but also by keeping the bud union at a safe height. The bud union itself is a weak point and particularly susceptible to gummosis diseases.

Shield or **T**-budding, using the inverted **T**, is the most satisfactory. The budwood should be young and plump. Old wood contains many dormant buds which do not grow readily ; young, angular wood is difficult to handle and is deficient in stored food reserves.

As previously discussed, budwood should only be cut from trees known to produce the desired type of fruit in abundance and only from such trees as show the least tendency toward single limb mutations. Budwood can be kept for some weeks if the ends are waxed and it is wrapped in damp moss but it is better to use freshly cut wood.

At the time of budding, all small trees should be destroyed.

In the stock, at a height of 10 inches, an inverted **T**-cut is made. The bud is cut from the bud stick, about three-quarters of an inch to one inch long, and is inserted in this cut, under the bark. The bud union is then wrapped with waxed cloth. Raffia wraps are used in semi-arid countries but whether or not they would be as satisfactory in the West Indies, the writer is unable to say. It is possible that waxed cloth will be found better than raffia because of the high rainfall and humidity.

Under the very favourable growing conditions of the West Indies, the newly inserted bud will probably start into growth with no further attention beyond a loosening of the wrappings after the first ten days. Should the bud be green and healthy after three weeks and yet remain dormant, the stock should be cut half-way through about 4 inches above the bud and bent over until the top rests on the ground. If this is followed with all of the trees in the nursery, each top in a row should be " lopped " in the same direction. It is quite possible that this " lopping " will hasten the development of the bud even when it grows out without forcing, as the semi-detached top of the tree furnishes much elaborated plant food to the roots.

When the bud has grown out about 9 inches, the stock can be cut away about an inch from the bud union. It is quite possible that it may be advantageous to leave the lopped top for three or four months as a source of plant food supply. While this practice is followed in some other countries, the writer hesitates to recommend it for the West Indies but suggests it for trial.

Should the top be removed entirely, the stub should be cut away when the bud has grown out about 18 inches. The cut should be made slanting in order that it may heal over quickly and soon. It should be painted with Bordeaux paste, white-lead paint, an asphaltum paint, or other wood preservative.

The staking of nursery trees leads to the production of a straighter tree than would otherwise be the case. Further, the tree can be headed at the desired height and all of the trees can be headed at a uniform height. A flat stake about 38 inches long and 1 inch wide should be driven into the ground beside each tree soon after the bud begins its growth and the bud shoot should be tied to this stake from time to time as it continues its growth. The ties should be made frequently in order that no outward bending of the little trunk may take place between the ties. Raffia is excellent material for this work. If the base of each stake is dipped in tar before it is driven into the ground, its life will be materially lengthened.

FIGURE 4.—A nursery in Florida, illustrating the method of training the young trees.

When the tree reaches about 36 inches in height it is headed 30 to 32 inches from the ground. This removal of the top causes several shoots to be thrown out, of which four to six should be left and the balance removed. These main scaffold branches should be spaced for 6 to 12 inches vertically on the trunk; in other words, they should not arise from a small space, as when this occurs a weak head is formed. The scaffolds should not arise from one side of the trunk alone but should be well distributed *around* the trunk. No scaffold branches should be allowed to develop under about 20 inches from the ground.

When the trees are large enough to be moved from the nursery, normally in 9 to 12 months, they should be irrigated well the day

before they are to be moved, unless soaking rains have recently fallen and the ground is in a very moist condition. A trench dug or ploughed along one side of each row greatly facilitates the digging out of the trees.

Trees that are to be transported any distance should have the scaffold branches cut back to 6 inches. It is probably not necessary to remove the leaves, as is frequently done in drier countries. If the trees are to be planted within a few minutes after removal from the nursery, the cutting back of the scaffolds may be omitted.

At the time of transplanting, all small, weak trees should be discarded as they are inferior to the well-grown, vigorous trees and will always remain so. All trees with deformed roots should also be destroyed. Heavy culling in the seedbed will greatly reduce the percentage of inferior trees found at this stage.

A nursery tree of the best type and grown in the best manner cannot be produced for less than 2*s*. When it is considered that the net value of the crop produced annually by each tree is from 10*s*. upward, it can be seen that a saving of a few pence in the original cost of the tree is negligible, yet a saving of a small sum in the beginning may mean great losses later. Further, considering the capital outlay in land and its preparation for planting, the annual outlay for labour and the care of the young grove, and several years of waiting for the trees to reach bearing age, it seems very absurd that any planter should think of saving a shilling a tree in its first cost and pay little attention to the inherent quality of the tree, when by so doing his large investment in time and money may be imperilled. Planters should insist on getting the best nursery trees that it is possible to produce ; the cost of such trees, within reason, is entirely immaterial.

Whether the prospective planter should grow his own trees or purchase them from a nurseryman is largely an individual question. A beginner with no previous experience in citrus fruit growing should purchase his trees from a reliable nurseryman. A man with an established grove who wishes to extend his plantings may care to grow his own trees. It is a fallacy to presume that a few hundred trees can be grown more cheaply than they can be purchased. The nurseryman knows his business (in some few cases at least) and through specialized and large-scale work can produce good trees just as cheaply and usually more cheaply than the small grower can.

When trees are to be purchased from a nurseryman, the grower should make certain that the nurseryman is using budwood taken only from parent trees of known character and that he is following the most careful stock selection, according to the lines mentioned heretofore. Trees that are only one year from bud should be specified in placing any order. Such trees stand transplanting better than older ones, but the chief point in favour of the young tree is: if the tree is large enough for sale in 9 to 12 months from the time of budding, it is fairly good evidence that it has been budded on a rapidly growing stock and as such is an inherently vigorous tree.

The planter should insist that the trees be supplied "bare root" in order that any with deformed roots may be detected and rejected.

Care of the Young Grove.

Young trees should be given continual attention. An inspection of each tree (by the planter himself and not by unskilled labourers) should be made at least every two months. Any undesirable condition can thus be found in its early stages when remedial measures are the easiest and most economical to apply.

Weeds and "bush" should be cut down whenever necessary with a machete (cutlass), the cut material being allowed to remain where it falls. Such growth should never be allowed to become so rank as to interfere with the growth and development of the young trees. At all times an area extending 6 feet on each side of each tree should be kept clean and in this area vegetation should *never* be allowed to develop to a height exceeding 2 feet. Clean cultivation in this area through an occasional light forking may be best but there is no evidence in support of this point. Should such an area be kept entirely clean, some of the cut weed growth from the centres of the rows should be strewn in this clean area when it is cut.

For the first few years until the trees come into good bearing, the principal care of the grove will consist of controlling weed growth, keeping a close watch for depredations of insect pests and giving an occasional light pruning. In carrying out the latter operation, the object should be to remove any branches that arise from undesirable positions. Should suckers arise, they should be removed, unless they can be utilized to make a better balanced tree. When two branches cross, one should be removed, in whole or in part. No branches should be cut back in such a way as to leave a stub.

If a branch is not to be removed entirely, it should be cut back to a lateral. If a branch is to be cut away entirely, make a clean and smooth cut that will heal over readily. Any cut over an inch across should be painted over with a wood preservative. If a tree is properly trained from the time it is planted, cuts of this size will rarely ever have to be made. In pruning grapefruit trees, a good maxim to follow is: when in doubt, leave it.

Should any scale insects attack the young trees they should be thoroughly sprayed with one of the usual sprays used for such pests, such as whale oil and soap, resin wash, soap and water, or the commercially prepared insecticides. The orange dog, a caterpillar that consumes young orange and grapefruit leaves, is best controlled by hand picking.

FIGURE 5.—A grapefruit tree recently planted. It had no training in the nursery and on planting in the field should have been staked. Compare with the trees shown in Fig. 4.

For the control of the " parasol ant " (or the weevy ant of British Honduras) or the black stingless bee (*Melipona silvestriana*, probably the same as the " drunken Bayman " of British Honduras) the writer is unable to make any suggestion beyond searching for and destroying the nests, by mechanical means or through the use of cyanide.

Under average soil and moisture conditions in Trinidad, Dominica, St. Lucia or Grenada, the use of fertilizers in young groves is not necessary. As long as the trees are healthy and vigorous, fertilization need not be considered.

Fertilization.

In California, Palestine, Florida, South Africa and Spain, the item of fertilization forms a considerable portion of the annual grove expenditure. In Palestine, for example, the average cost per acre per year is £17. In Florida commercial fertilizers are used in large quantities, from 60 to 90 pounds per tree per year. On the rich soils so plentiful through the four islands under discussion, and in British Honduras as well, the required outlay for fertilizers is little or nothing. The subject of soil fertility is too long for detailed treatment in this paper and in regard to the West Indies it

Figure 6.—A young grapefruit tree that was not trained and formed a head too low. Compare with Fig. 7.

is one on which the writer can only give conclusions based on comparatively short observations. Experimental work in California is of no value in the West Indies because of widely differing climatic and soil conditions between the two areas. In considering the ordinary fertilizing practice in Florida, planters should realize that the soils of Florida are practically pure sand and are very deficient in available plant food. The West Indian soils, for the most part, are heavy, contain a great abundance of organic matter and are extremely fertile. Observations in South Africa, Spain or Palestine cannot be used as a guide in the West Indies because of marked differences in climate and soils.

While it is evident that fertilization of the soil is essential to heavy fruit production and good tree health, it is by no means clear as to the kinds or quantities of fertilizers that should be added to the soil in order to get the best results, nor is it evident at what stage in the life of the grove fertilization should be commenced. The question varies with the climate and soil and is one that is frequently peculiar to the individual grove. The problem with the rich soils of the West Indies is not one of building up soil fertility but rather one of maintaining the fertility already present. Soil fertility, under tropical conditions, is directly associated with the organic content of the soil, hence any factor that leads to the

FIGURE 7.—A young grapefruit tree with a good head. Compare with Fig. 6. Photo taken in Trinidad.

establishment or maintenance of an abundant supply of organic matter in the soil, will presumably establish or maintain an abundance of available plant food. Until further evidence is available, planters should consider their soil fertility problem in this light.

The presence of a large quantity of organic matter is advantageous because through its decomposition, additional plant food is made available through the action of weak acids on the adjacent soil particles ; it is greatly retentive of moisture, yet a soil that is rich

in organic matter is usually better drained and aerated and suffers less from surface erosion than other soils ; its presence prevents packing and hardening of the soil.

From observations in the islands, in British Honduras and in Jamaica, the writer is able to recommend the practice known in the latter country as " bush mulching." It consists of cutlassing the weed growth in the grove from time to time during the year and letting the cut grass remain on the surface of the soil between the trees. In addition, grass and small bush from adjacent land may be cut and strewn through the grove in order to supplement the organic matter produced on the land itself. This practice can be carried out very economically as the only expenditure is for labour.

FIGURE 8.—Twelve year old grapefruit in British Honduras.

Numerous bearing groves are to be found in the West Indies, British Honduras and Jamaica that have had no soil treatment beyond " bush mulching " and where the mulching has been carried out thoroughly the groves are in good condition and are bearing well.

One interesting example can be given showing the effect of mulching upon the recovery of an abandoned grove. In a certain area in Dominica, a grove was planted some ten years ago and soon afterward was allowed to revert to bush, upon the abandonment of the estate due to the ravages of the wither-tip of the lime. Three years ago a portion of the grove was cleared of bush, surface drains were dug and an abundant quantity of organic matter was strewn

through the grove, supplemented with a small quantity of cattle manure. The soil was not cultivated, nor was any fertilizer used beyond the organic matter mentioned. Each year the grass was cutlassed whenever necessary. When first cleared from bush the grapefruit trees were nearly dead, were tall and spindly with a few leaves at the ends of the branches. They have since made a remarkable recovery, have filled out to their normal shape and are healthy and vigorous in appearance. The crop from these trees for the season 1927–28, three years after removing the bush, averaged 500 fruits per tree and was sold on the London market at very remunerative prices.

Mulching alone may prove to be insufficient over a long period of time and it certainly cannot be used to the exclusion of everything else on poor soils. It is quite possible that it will be found advisable to supplement mulching with the use of manure or commercial fertilizers but information on this point will not be forthcoming for some years.

Commercial fertilizers should not be used unless the planter is satisfied that their use is necessary. Statements of fertilizer dealers should not form the basis for the fertilizer practice to be adopted, nor should consideration be given to soil analyses. If the trees are healthy and vigorous and bearing well, they are in no immediate need of fertilizers. If the annual growth is unsatisfactory, if production declines or if the foliage becomes pale in colour, fertilization may be the solution of the trouble. Before acting on this conclusion, however, the planter should explore other factors such as insect injury or disease and particularly drainage. Waterlogging of the soil is highly injurious and may readily occur under conditions of heavy rainfall. Fertilizers are expensive and should only be used as a last resort.

One frequently hears of the injurious results in Florida occurring when manure is used in the citrus groves. Planters in the West Indies should not assume that injurious effects will follow their use of manure. Because of the sandy nature of the soils of Florida, the nitrogen in the manure becomes available very rapidly and probably results in over-stimulation of the trees. Manure added to the heavier West Indian soils would not react in the same way.

The planting of a leguminous crop between the trees, as is practised to some extent in Dominica, may prove more beneficial than keeping the ordinary weed growth. An excellent legume for interplanting is the *Tephrosia candida,* which makes very rank, succulent growth, thus supplying a large quantity of mulching material. In the event that the planter wishes to augment the supply of organic matter produced within the limits of the grove itself, it is suggested that plantings of *Tephrosia* be established near the grove. It can be cut back to 6 inches from the ground three or four times a year and placed on the ground between the trees.

Although continual mulching for three or four years has proved injurious in California, there is ample evidence that it can be carried out for ten or fifteen years under tropical conditions with beneficial results.

Cultivation.

It is generally accepted by an increasing number of experimental workers that the sole objects of cultivation are (1), the preparation of a seedbed, as for sowing a green manuring crop ; (2), the incorporation of fertilizers ; (3), the preparation of a soil to receive moisture ; (4), the destruction of weeds. Cultivation of the soil probably does not conserve moisture except in so far as it destroys weeds.

When cultivation is carried out with one or more of the abovementioned objects in view it can be considered as being beneficial, otherwise it is unnecessary. Consideration of these four objects in the light of conditions existing in the citrus fruit plantings of the tropical West Indies shows that cultivation is probably unnecessary.

For the establishment of a green manuring crop such as *Tephrosia,* a very shallow forking of the soil is sufficient.

The second point, the incorporation of fertilizers, does not apply as the mulching recommended is purely a surface operation. Should commercial fertilizers ever be used, their distribution on the surface of the soil would be satisfactory. The rainfall is sufficient to carry them down to the root system which, as a matter of fact, is very close to the surface.

The third point, preparation of a soil to receive moisture, is not applicable except in the nursery, as irrigation of a grove is not required. A clean cultivated grove would suffer severely from erosion, while a grove under grass or a cover crop would not be affected by washing caused by heavy rains.

The fourth point, destruction of weeds, is applicable in the case of the young grove and in the nursery. It is probably advisable to keep an area clean on each side of the young trees. With bearing trees, of the desired drooping habit of growth (*see* Fig. 10), weed growth near the trunk is partially controlled by the shading effect of the branches. Conservation of moisture through the destruction of weeds is not necessary because the annual rainfall is ample for the needs of the trees and the weeds and is well distributed throughout the year.

Under the conditions in the areas recommended for grapefruit planting, the root system of the trees will be found very close to the surface of the soil, the bulk of the roots being in the upper 12 inches of soil. The upper 6 inches contain a large quantity of fibrous feeding roots and as such is the case cultivation could easily do a great deal of harm to the trees.

Cultivation of mature grapefruit or orange plantings in the West Indies in general is not recommended as no object can be gained by cultivation under the climatic and soil conditions in question. This statement must not be interpreted to mean that neglect of the grove is recommended. It is of the utmost importance that the growth of the natural vegetation, or green manuring crop used in substitution thereof, should be kept under proper control. *The weed growth must be cut regularly and never be allowed to interfere with the development of the trees.* Further, great care must be taken to keep *all* weed growth at least a foot away from the base of the trunk, regardless of the age of the trees. Weed growth close around the trunk is an important factor in the development of crown root diseases, the most common of which is collar rot.

Diseases.

Of diseases that affect the trees themselves, the trouble known as " gummosis " is by far the most serious. There are no data available to show the exact cause or causes of the forms of gummosis occurring in the West Indies and British Honduras. Gummosis of the limbs themselves is not common but the crown root type, or collar rot, occurs fairly frequently. Other forms of root rots may affect the sour orange root but on this point there is no information.

The sour orange root stock is extremely resistant to disease, hence its use is recommended to the commercial exclusion of all other stocks. It is virtually immune to collar rot and probably immune to the " red root " so serious in Dominica with seedling West Indian limes.

Collar rot is a fungous disease attacking certain species of citrus plants at the base of the trunk and extending downward on the crown roots. The disease does not extend upward beyond 2 or 3 feet. Cracks form in the bark and the bark and cambium layer are eventually killed. The dead bark usually strips off from the trunk but may shrivel or contract and give the affected area a sunken appearance. The trunk may be girdled in time and the death of the tree result. Gum may or may not form, depending largely on certain external conditions. (*See* Fig. 9.)

FIGURE 9.—Collar rot on seedling or low budded grapefruit in British Honduras.

The conditions leading to the development of collar rot are (1), the presence of water or moist soil in contact with the trunk over a sufficiently long period of time ; (2), low planting, low budding or the accumulation of soil around the trunk ; (3), a susceptible root stock ; (4), bark injuries, particularly near the ground, such as would result from careless use of a cutlass ; (5), favourable soil and air temperatures.

As previously mentioned, trees should be planted as high as possible, regardless of the height at which they stood in the nursery.

The continual presence of thick weed growth around the base of the trunk should be avoided as it keeps the bark moist and tender and hence very susceptible to disease invasion. An accumulation of soil around the base of the trunk is very injurious. The crown roots should always be kept slightly exposed as no harm will be done and one cause of collar rot will have been eliminated.

Budding should be done at a height of 10 inches from the ground in order that the susceptible grapefruit or sweet orange wood may be kept a safe distance from the ground. The bud union itself is particularly susceptible as a point of infection and should be kept at least 10 inches from the ground.

The treatment of collar rot lies chiefly in its prevention through following the points given. Should the trouble develop, however, all diseased bark and tissue should be carefully scraped away and all soil should be removed from the base of the tree in such a manner as to leave the crown roots exposed for at least a foot. Soil below the crown roots should be removed as well as that above them. After scraping, the crown roots and the scraped area should be painted with a disinfectant such as Bordeaux paste or tar paint.

The recovery of trees that have become badly affected with collar rot can be greatly accelerated by "in-arching" with small sour orange seedlings. Trees that have been completely girdled can be restored to vigour in this way. In-arching is a very simple operation that can be done successfully by all growers. Seedling sour oranges 24 inches to 30 inches high are planted about a foot away from the trunk of the tree to be treated. Strong, rapidly growing seedlings should be chosen for this purpose. Three or four should be set around a mature tree. When these seedlings reach a diameter of three-eighths to one-half inch at the height at which it is proposed to make the in-arch, the work can be done. The point of in-arching should be several inches above the diseased area and in no case should it be under 10 inches from the ground.

The steps to be followed are :—

(1) Cut off the top of the seedling at the desired point, making a sloping cut two or three inches long, the cut surface facing the large trunk to be treated.

(2) The bark of the large tree should be cleaned and if too thick should be scraped down somewhat at the point of in-arch. The seedling should have one or two small holes drilled or punched in the sloping cut at right angles to it.

(3) The cut end of the seedling is inserted in the cut in the bark of the diseased tree, a three-quarter inch thin nail being carefully driven in each punched hole and the point of in-arching is then covered with warm grafting wax. The object of using the small nails is to keep the seedling tree in firm contact with the trunk.

It is not essential that the seedling trees be planted around the diseased trees before in-arching. Through the use of seedlings of a sufficient size, the in-arching and planting can be done at the same time. The operation should be done at a time when the trees are in a rapidly growing condition in order that the bark may slip easily. The trunks of mature trees will frequently have a ridged or fluted surface. In such cases, the in-arch should always be made on a ridge as this area is more rapidly growing than the adjacent depression.

One of the most important steps in the control of collar rot or any form of tree disease is a semi-annual inspection of each tree in order that the trouble may be found in its early stages, at which time it is not difficult to treat successfully.

Insect Pests.

As the writer is not an entomologist, he is unable to give definite recommendations for the control of insect pests under tropical conditions. The citrus insect problem in the West Indies is quite different from that of semi-arid countries.

Fumigation for the control of scale insects as practised in South Africa and California is out of the question because of climatic conditions. In areas of continually high humidity, fumigation is not a commercial success. Spraying for scale control may occasionally become necessary in the drier areas but as a rule the scale insects are well controlled through the action of entomogenous fungi. In dry areas or in dry seasons, the work of these fungi is checked and scale insects increase in numbers.

Should rust mite injury be serious in any section, spraying with lime-sulphur or dusting with sulphur containing about 8 per cent. hydrated lime will give control. When rust mite injury is expected, a

spraying or dusting should be given when the fruit has reached an average diameter of 1 inch. Further treatment is given whenever rust mites become numerous.

For details of miscellaneous insect pests and the recommended manner of treatment, growers should consult their local Department of Agriculture.

Varieties.

A country that produces a large quantity of fruit of a small number of varieties is able to approach uniformity of its product far more than a country that grows many varieties. Uniformity of a given product is of great value in the large markets and this point is so evident that it need not be discussed here.

The growing of seedling trees should be discontinued and fruit from existing seedling groves should not be shipped unless it is exceptionally good. Fortunately, British Honduras and Jamaica are the only areas where the seedling grapefruit has been planted in groves.

It is recommended that the West Indies should plant the Marsh and Duncan grapefruit. Both varieties are entirely satisfactory and growers should limit their plantings to these two varieties to the exclusion of others. From a marketing viewpoint, it is extremely desirable that there should be uniformity of varieties between the various islands. Additional varieties will probably be found to be suitable but unless they are *better* than the Duncan and Marsh, it would be better, for the sake of uniformity, not to plant them on a large scale.

Tree Records.

The unit of production in citrus fruit growing should be the individual tree. The total production of fruit per acre is not a true indication of conditions in the grove as the bulk of the fruit may be coming from a few trees only. For example, a given acre of land on which are planted 50 grapefruit trees may produce 300 cases of fruit, an average of 6 cases per tree. A study of such a planting would probably reveal the fact that the bulk of the fruit was being produced by 50 per cent. or less of the total number of trees. The unproductive trees are being maintained at a loss and if they could be made more productive, the returns to the planter would be greatly increased. A grove as a whole may produce a satisfactory crop but if even a quarter of the trees are not bearing well, the production is not as high as it should be.

Available space does not permit a full discussion of the uses and manner of keeping tree records.* Briefly speaking, each tree is given a numerical identity. Each row of trees is numbered and each tree in each row is numbered. Thus, the tenth tree in the fifth row is Tree 10, Row 5 ; the tenth tree in the twelfth row is Tree 10, Row 12. The row and tree number can be painted on the trunk of each tree, one above the other, using white lead paint.

Shortly before the fruit is picked, an estimate is made of the fruit on each tree and the estimate is recorded on a suitable form made for this purpose. The most simple method of estimation, one that eliminates variation in quantity of yield due to climatic factors, is to class the production of each tree as being very good, good, medium, poor or very poor. Each of these classes is given a representing number : 5, very good ; 4, good ; 3, medium ; 2, poor ; 1, very poor. Only the number is recorded on the estimate production chart.

When records have been kept for four years, the planter can classify his trees as being profitable or unprofitable and take steps accordingly.

When a tree is found to bear poor crops over a period of four years, the unproductiveness is due to inherent disability, unfavourable stock reaction or to unfavourable environmental conditions. If the tree is not capable of bearing well, it should be removed or top-worked. Top-working of a tree that is a poor bearer because of an abnormal stock reaction will not alter the condition, hence such a tree must be removed entirely and replaced with a new one. If the failure to bear well is due to some unfavourable factor of environment, the obvious remedy is to change this factor. As a general rule, low production is due to poor environment, either natural or cultural.

A tree or group of trees may have been planted on shallow soil, poorly drained soil, sandy soil ; a tree with a deformed root system may have been planted by error ; some trees may have collar rot ; the soil in a particular spot may be lacking in fertility, etc.

Factors causing low production can be studied most successfully when a map of the grove is made, on which small squares represent each tree. After a period of four years, those trees that have borne good or very good crops (classes 4 and 5) can be considered as being

* Copies of Transvaal University College Bulletin 8, " Citrus Tree Records and Their Uses," can be secured upon application to the Registrar, Transvaal University College, Pretoria, South Africa.

profitable ; those that produce medium crops (class 3) are neither profitable nor unprofitable, they give no returns above expenses ; those that produce poor or very poor crops (classes 1 and 2) are certainly unprofitable.

The best results from this grouping of trees is to be found in filling in the above-mentioned map in three colours, green representing classes 4 and 5, the profitable trees ; black representing class 3, the self-supporting trees ; and red representing classes 1 and 2, the unprofitable trees. Each square on the map represents one tree and each square is coloured according to the productiveness of the tree it represents.

FIGURE 10.—A mature grapefruit tree of good size and shape. It is probably about 20 years old. Photo taken in Florida.

We will presume that the distribution chart shows a group of trees in one part of the grove that are unproductive. It is not likely that the unproductiveness in such a case is due to inherent or to stock factors, as where such occurs the poor trees are usually scattered through a grove with no regularity or grouping. The unproductiveness of this group of trees is therefore probably due to one or more environmental factors, examples of which have already been given. The particular factors can be determined and remedial measures taken as warranted.

Through the use of individual tree production records, the efficiency of a grove can be materially increased and to an interested planter a study of this nature can not only be very profitable but extremely absorbing.

Picking and Packing Operations—Fruit Decay.

The marketing of citrus fruits is as important as the actual production of the fruit, as the production itself is carried out in vain unless the fruit can be marketed successfully. The object of production is the successful and profitable marketing of the article produced. The fruit must be picked, packed and shipped under such conditions as will ensure its arrival in the markets in a condition that will make it attractive and satisfactory to the trade.

The chief causes of decay in grapefruit under tropical conditions in the West Indies are stem-end rot (*Diplodia* spp. and *Phomopsis* spp.) and the blue-contact and green moulds (*Penicillium italicum and P. digitatum,* respectively). The latter two are commonly grouped together under the general term " blue mould."

Where losses in transit from stem-end rot are serious, it is suggested that an attempt at control be made through carrying out the following points :—

(1) Keep the trees in a vigorous, healthy condition as fruit from such trees is more resistant to the attack of the fungus causing the disease. Fruit from seedling grapefruit trees, which are usually unthrifty and full of dead wood, will probably be found to suffer much more from stem-end rot than fruit from thrifty, budded trees.

(2) Dead wood should be removed from trees in groves in which the fruit is subject to the disease.

(3) When the disease is very troublesome, spray the young fruit once or twice with 3–3–50 Bordeaux mixture.

Full details regarding Phomopsis stem-end rot, blue-contact and green mould, collar rot and other citrus diseases can be found in Fawcett and Lee's " Citrus Diseases and Their Control," McGraw-Hill Book Company.

Blue-contact and green moulds usually attack citrus fruits only at a point of injury. If fruit is shipped that is free from mechanical injuries, the loss from decay in transit due to these fungi will be reduced to a minimum.

Prevention of mechanical injuries to the fruit in the picking, packing and transport operations is not difficult to secure. Decay in transit of 10 per cent. or more is unnecessary and forms a serious handicap to the grower. Not only does the shipper lose financially

but the particular brand of fruit and its country of origin gain an unenviable reputation. With increasing competition in the markets, a grower or country whose fruit is known to be free from excessive decay, possesses a great advantage over other growers or areas whose fruit may or may not arrive in sound condition.

Pickers should be taught the importance of extreme care in handling the fruit. Pickers should be equipped with gloves in order that finger nail scratches may be avoided.

Fruit should never be dropped or bruised in any way at any stage of the handling. Dropped fruit should be left on the ground or sold locally.

Clippers should be used of a design that will not cause injury to the fruit.

The fruit should be placed in suitable containers and these should always be kept free from projecting points or splinters. The containers should be shaken out just before fruit is placed in them in order that any foreign material such as twigs or small grains of sand may be removed.

Everyone handling the fruit should be taught that it is a highly perishable article and must be handled as such.

The stem should be cut flush with the button but should not be cut so close as to injure the button. No projecting stems should be left, even though only a thirty-second of an inch long, as fruit coming in contact with such a projection will be injured.

Fruit should never be piled over 18 inches deep. When fruit is piled deeply, the pressure on the lower fruit is sufficient to cause bruising ; any grit or twigs at the bottom of the pile will be pressed into fruits on the lower layer ; any projecting stems will be pressed into the fruit above.

No fruit should be picked when the trees are wet from rain or dew and no fruit should be picked for two or three days (in extreme cases, more) following a long period of rain.

Fruit should never be exposed for more than an hour to the sun.

Fruit should be wilted or cured for as long a period as may seem advisable before it is packed. This period will vary with weather conditions, storage facilities, and with the maturity of the fruit. From five to ten days is desirable in most cases.

An abundance of grapefruit of excellent quality is shipped to the English and Canadian markets. Growers should not ship any fruit that is not fully mature. In countries that have no legislation setting the minimum degree of maturity, the tendency is for some growers to ship immature fruit. If the ever-expanding grapefruit market is to continue its present rate of expansion, immature fruit must not be shipped.

FIGURE 11.—A well-grown, five-year Marsh grapefruit, showing a good type of growth. Photo taken in Florida.

Grapefruit can be held on the trees for some weeks after picking maturity has been reached. It can also be held for several weeks in common storage. By using a combination of storage on the tree, followed by storage in a cool, well-ventilated room or basement, the marketing season can be materially lengthened.

If handled carefully, grapefruit can be transported for a considerable distance before it is packed. There is no need, in any of the West Indian islands except Jamaica, for more than one co-operative packing house. In Trinidad, for example, one co-operative house in Port-of-Spain can handle fruit from all of the producing areas.

The islands of the West Indies that can produce grapefruit can be considered as an economic unit. Should the industry assume large proportions in these islands, it will be extremely desirable to have a single marketing channel or organization for all of the fruit in order that the islands shall not compete with one another and that *West Indian* grapefruit shall compete as a unit against that from other countries. Co-operation between the islands is essential in such matters as uniformity of grading and varieties if West Indian grapefruit is to gain the place in the markets that it deserves.

The creation of a single brand for all of the islands is not desirable, nor would it prove successful. The writer feels that each island, for the time being, should ship grapefruit under two grades, extra choice and standard, and that each grade in each island should be packed under a distinctive brand. Dominica would ship extra choice and standard grades, we will assume, under the " Dom " and " Forest " brands respectively. Trinidad would also ship under exactly the same grades but would call them " Humming Bird " and " Linnet " brands. Thus, uniformity of grading would be established, yet the fruit of each island would stand on its own merits. The creation of a single brand covering both grades is undesirable because the lower grade will depress the price that the higher grade should realize.

Standard containers should also be adopted. It is suggested that the California type of box is the most suitable.

Any island producing a thousand or more boxes of fruit, with an increase in production a matter of a year or two distant, should consider the advisability of erecting and equipping a centrally-located, co-operative packing house. While such a house, operating on a small scale, cannot handle fruit any more economically than the individual members, the advantages to be derived through such a house are many. The co-operative association can purchase supplies cheaper in large quantities than in small quantities. The members are relieved from the necessity for learning all of the details of fruit packing and handling. Co-operative ownership of field boxes, curing boxes, ladders, clippers and picking bags is more economical than would be the case if every member were to own this equipment himself. The greatest advantage to the growers, however, is in the fact that co-operative packing of fruit insures standardization of grading and packing and general improvement of all handling operations.

If the West Indian islands will plant grapefruit under proper conditions of soil and rainfall, plant the best trees obtainable and give them proper attention, pick, pack and grade the fruit in the best manner, there is no reason why they cannot supply ever-increasing quantities of grapefruit to the United Kingdom and Canadian markets. Natural conditions of soil and climate are unsurpassed—the future of the industry lies with the growers.

IMPORTATION OF CITRUS MATERIAL.

In view of the risk of introducing dangerous citrus diseases and insect pests it is advisable that any bud-wood or other material for propagation required from other countries should only be obtained through the local Departments of Agriculture and with the fullest precautions to ensure their freedom from diseases and pests.

NOTES ON COLONIES VISITED.

(1) BAHAMA ISLANDS.

The Bahama Islands are a chain of islands with a total area of 4,403 square miles, lying south-east of Florida. The soil is very shallow as a rule, consisting for the most part of pockets of varying size and depth in the limestone rock. The rainfall varies from 30 inches to 60 inches.

Although the Bahamas were once the site of a small citrus fruit industry, the present production of oranges and grapefruit is not sufficient to meet the local demand. The largest export was probably in 1905–06, when 2,000,000 oranges were exported. On the basis of 150 fruits per box, this quantity equalled somewhat over 13,000 boxes. The export trade gradually declined because of increasing competition with Florida and California. The McKinley tariff added a further handicap to the trade. With the introduction into the Colony, about 1912, of the blue grey citrus fly (syn. black fly) *Aleurocanthus woglumi*, the bulk of the citrus fruit plantings were killed.

Soil and rainfall conditions throughout the Bahamas are not suited to citrus fruit growing on a commercial scale. There are very few places where any depth of soil is found. The existing soil is rich in organic matter when first cleared from the native bush and is very fertile. The fertility is due largely to the content of organic matter and is quickly exhausted. When crops are planted, the vegetative growth is kept down and the organic content of the soil is depleted rapidly. Any plantings of fruit that are set out for local market purposes must be heavily fertilized, preferably with organic manures.

The depredations of the blue-grey fly were undoubtedly intensified because of a weak condition of the trees resulting from low rainfall, depleted soil fertility and general neglect. The insect can be controlled by frequent sprayings but the operation is costly.

The distribution by the Board of Agriculture of some 6,000 trees during the past two years (1927–28) will undoubtedly increase the quantity of fruit available for the local market. Further efforts should be made to increase the local fruit production, but there seems no possibility of re-establishing an export trade in oranges and grapefruit.

(2) BRITISH HONDURAS.

The colony of British Honduras offers an excellent opportunity for individuals or companies desiring to take up grapefruit growing. The colony is south of the Mexican province of Yucatan, has an area of 8,598 square miles and is heavily wooded. Along the coast the land is low lying and generally poorly drained.

Soils along the lower reaches of the Sibun and Belize rivers are too heavy, too shallow and too poorly drained to justify any large-scale planting of citrus fruits on them. Sandy soils of the " pine ridge " type are found some distance in from the coast. While they can be used for citrus fruit production their light nature and low content of organic matter necessitate heavy fertilization, with a resulting increase in production costs. Until better soils have been fully developed, it would seem unwise to use the sandy soils.

The most suitable area for grapefruit production in British Honduras is in the Stann Creek Valley. In addition to possessing an abundance of excellent soil, the valley has a railway service to the coast that greatly facilitates the transport of fruit. Rainfall in this area varies from 75 inches to 100 inches per year, generally increasing as one goes further inland.

There is no direct communication with England but fruit can be shipped via New York with transhipment at that point. Shipments to Canada would be transhipped at Kingston, Jamaica.

Labour is not as plentiful as in some of the West Indian Islands and is generally paid about $1 (4*s.* 2*d.*) a day, which is much higher than in the West Indies.

The bearing acreage of budded grapefruit trees is small, less than 25 acres, but considerable new acreage is being planted and production will increase rapidly in the near future. Owing to the very low production costs and the high quality of the fruit that is produced, extension of the industry is fully warranted.

Though in certain areas in the country there are small plantings of seedling grapefruit, the seedling tree is undesirable in every way and no further planting of seedlings should be made.

The fruit produced by seedling trees is variable in shape, flavour, quality and other points, and is generally much inferior to the uniform fruit from budded trees of standard varieties. The shipment of seedling grapefruit from British Honduras or from any other Colony, should be stopped, as in view of the severe competition in the large markets it is of the utmost importance that producing Colonies should develop a reputation for uniform fruit of high quality. Such a reputation cannot be acquired if seedling grapefruit are exported and the writer would urge that in British Honduras and the West Indies growers should confine their plantings to the Marsh and Duncan varieties.

An agricultural officer with citrus fruit experience has been appointed to the Forestry Service of British Honduras and planters are thus assured of having available a source of reliable information on production and handling problems.

(3) DOMINICA.

Dominica is one of the Leeward Islands and has an area of 291 square miles. It is one of the most mountainous of the West Indian islands, the mountains rising very abruptly from the sea. The rainfall varies from 60 inches to 300 inches, the rainfall in the mountains being much greater than along the leeward coast.

Road communication in the island is not as good as in some of the other islands.

The climate, while quite warm in summer, is not unduly unhealthy and can be considered as better than in some of the other islands.

The chief agricultural enterprise of the island is the cultivation of the seedling West Indian lime, limes and lime-products such as fresh limes, lime oil, concentrated lime juice and raw lime juice forming about 80 per cent. of the exports from the island.

Since the advent of the " wither-tip " disease of the lime (*Gloeosporium limetticolum*) in 1922, the estimated acreage in limes has fallen from 6,000 acres to 3,500 acres. Lime cultivation in the districts more than a mile from the leeward coast has been entirely abandoned due to the ravages of wither-tip. Along the leeward coast from Soufriere to Portsmouth is a belt of land subject to rainfall much lower than that occurring further inland. In this belt the losses from wither-tip have not been so severe as to render lime cultivation unprofitable. In the mountainous interior it is not likely that commercial production of the West Indian lime will ever again prove profitable because of the losses from wither-tip.

Beginning about September, 1927, a new trouble became epidemic, that known as " red root." Many thousand trees have been lost during the last year and many more will be lost. " Red-root " does not affect lime trees budded on the sour orange root stock and trees lost through " red-root " should be replaced with trees budded on this stock.

As the lime industry has suffered great losses through wither-tip and " red-root", it is essential that a substitute industry be found without delay. The island is admirably suited to the development of a large grapefruit industry, having a suitable climate and an abundance of good grapefruit soil.

The present production of grapefruit is about 500 boxes a year. A small increase will take place in the next two or three years but there is little likelihood of any marked expansion under present conditions. Grapefruit cultivation should be confined to those areas where lime growing is no longer possible. The grapefruit is not attacked by wither-tip and when budded on the sour orange root stock, as it should be, is immune to " red-root."

Although Dominica is pre-eminently adapted to grapefruit cultivation on a large scale, it does not seem likely that any great development will take place in the near future as there are practically no individuals in the island who can carry out the planting. Climatic conditions are suitable, the grapefruit thriving under rainfall as high as 200 inches, soil conditions are excellent and shipping facilities exist for the transport of the fruit to England or Canada, but there is a complete lack of local people with the necessary capital to start the industry.

Capital of £5,000 is necessary for the planting and care of about 20 acres of grapefruit from the initial stages to commercial bearing five years later. Settlers with this amount of capital are not numerous and it would seem that the only chance for creating a grapefruit industry in Dominica lies in the field of company development.

(4) GRENADA.

The island of Grenada in the Windward group, has an area of 120 square miles. It is mountainous, heavily wooded, and has a rainfall varying from 35 inches to 200 inches. There is an unknown quantity of soil suitable for grapefruit culture. The bulk of the best soil is planted to nutmegs and cacao, but several hundred acres could no doubt be found that could be planted to grapefruit. Soils in general are heavy.

Grenada has no citrus fruit industry at present, but during the last two years (1927–28) the Agricultural Department has distributed about 4,000 budded grapefruit plants. Some of these have been sent out in lots of 50 or less and can be disregarded from commercial consideration. There are about 3,000 plants in commercial groves and the production in five years' time will be about 5,000 boxes of fruit. Further planting on a moderate scale is to be expected.

As Grenada is directly associated with Trinidad in agricultural matters, the experience of Trinidad in the development of its grapefruit industry will always be promptly communicated to the planters in Grenada.

(5) JAMAICA.

The island of Jamaica, with an area of 4,207 square miles, lies just south of the eastern portion of Cuba. The present export of grapefruit is approximately 100,000 cases a year and an extension of the industry will probably take place in the near future.

Cultural conditions are most favourable and fruit of high eating quality is produced. The appearance of much of the fruit is poor, chiefly due to the presence of the " black fly," *Aleurocanthus woglumi*. With careful washing and polishing of the fruit, its appearance is greatly improved.

The bulk of the Jamaican plantings are owned by peasant proprietors, with holdings of five acres or less. In holdings of this size grapefruit and other citrus fruits are not grown as a distinct crop but occupy land that is also used for such crops as bananas, coffee, tannias, etc. The result is that little care is given the trees and the quantity and quality of the fruit produced leaves much to be desired.

The bulk of the larger plantings of ten to twenty acres have not been given sufficient care in recent years to maintain them in good condition. Cattle are usually run through the plantings, no fertilization is followed and little or no attempt is made to control insect pests. The result is an unthrifty condition of the trees, low production of fruit and the production of scaley and dirty fruit. This neglect has come about through the loss of the American market due to the McKinley tariff and a lack of direct communication with England.

The growing of seedling trees is greatly to be deplored. Thousands of seedling trees have been planted throughout the island and Jamaican grapefruit is generally very variable. Budded trees of the standard varieties should be planted and seedling trees should be top-worked to these same varieties.

General cultural costs are lower than in California, Florida or South Africa, and fruit can be landed in the United Kingdom markets at a very reasonable figure. While the Elders and Fyffes line will not carry fruit for growers, the creation of a new shipping service, as is contemplated at present, will undoubtedly stimulate further grapefruit production.

The recent establishment of a fruit inspection service by the Government will greatly improve grading and packing standards and is to be highly commended. Handling conditions in the field and packing houses leave much to be desired, the fruit being treated in such a way as to be bruised and injured excessively. As the Florida production of grapefruit is increasing rapidly and as this fruit has a distinct market preference on the basis of excellent quality, appearance, grading and packing, it is very important that Jamaican and other West Indian shippers should ship fruit equal in all respects to that of their most serious competitor.

While large extension of planting in Jamaica is not recommended for the present, the export of grapefruit from the island can be at least doubled through giving more attention and care to the existing groves. Spraying for the control of rust mite, thrips and black fly, cleaning the trees of dead wood, lichens and wild pines, fertilization, improvement of picking and packing operations and general care of the plantings will result in a marked increase in the quantity and quality of the fruit shipped.

(6) ST. LUCIA.

The island of St. Lucia is one of the group known as the Windward Islands. It is a small island, having an area of only 233 square miles but, as is so true of the West Indies as a whole, it is very beautiful. It is mountainous for the most part but in some of the valleys is to be found a limited quantity of soil that is suited to citrus fruit growing.

There is no grapefruit industry in St. Lucia at present but a recent importation of trees was made that will form the nucleus for a small export trade in the near future. The quantity of land in St. Lucia that is available for commercial grapefruit plantings is very limited and it is not to be expected that a large fruit industry will ever be established. Most of the valleys that open out to the sea are of heavy soil with a high-water table.

There is no direct shipping communication with England but a good service exists with Canada. As Canada has established a preferential tariff of 1c. a pound in favour of grapefruit from the West Indies, it would seem possible for St. Lucia to produce a few thousand boxes of grapefruit for shipment to that market. With low cost of production and a preferential tariff, there is no reason why St. Lucia cannot find in Canada a ready market for grapefruit, provided it is of good quality, well graded and well packed.

Barbados with a population of 175,000 is only about 100 miles distant and a considerable quantity of fruits such as the orange, papaya and mango can be readily marketed there. Selected varieties of these fruits should be planted and they should be packed and handled with great care. Under present conditions it would be comparatively easy for St. Lucia to gain the reputation of being the source of supply of the best fruit entering Barbados.

(7) TRINIDAD.

The island of Trinidad with an area of 1,862 square miles, is the southernmost island of the West Indies and lies a few miles off the coast of Venezuela north of the mouth of the Orinoco.

With a population of some 350,000, extensive sugar, cacao and coconut industries and important oil fields, it is one of the most fortunate of the West Indian islands. The rainfall varies from 50 inches to 100 inches or over. The soil is generally very fertile and the quantity of land that can be utilized for agricultural purposes is large. Sections of the island are mountainous, but fertile valleys are plentiful and the extent of rolling and flat land is large. Soils in general are rather heavy except in the southern portion of the island.

The road system of Trinidad is excellent. The presence in the island of the Pitch Lake, the source of the bulk of the world's supply of asphalt, makes possible the building of good roads at a low cost.

Shipping communication with England is good and is of sufficient extent to handle all of the fruit that will be produced for some years to come. The journey from Trinidad to England takes about 14 days and, with careful handling and packing, grapefruit for the English markets need not be refrigerated in transit.

The grapefruit industry is small at present but planters are very anxious to extend their holdings. There are 2,450 bearing trees (35 acres), 11,924 non-bearing trees (168 acres) and approximately 30,000 trees (400 acres) will be planted in 1929. From an export of about 3,000 boxes of fruit in 1928, it is evident that in five or six years the export should reach approximately 75,000 boxes.

Increase in production can continue to an unknown degree should economic conditions justify it. The area of land that is available in Trinidad and suitable for grapefruit culture is unknown, but it is certainly several thousand acres in extent.

It would seem advisable to encourage plantings in the northern and central portions of the Island because (1) these areas have a greater quantity of suitable soil than the southern part of the island ; (2) proximity to Port-of-Spain, the point of export, means lower inland transport charges ; (3) proximity to Port-of-Spain is a big factor that will result in the successful operation of a central co-operative packing house at that point.

Steps have been taken by the Fruit Growers' Association to form a small co-operative company for the purpose of erecting and equipping a packing house to handle the fruit of the members. Successful operation of such a house will mean uniformity of grading and packing and the shipment of the bulk of the fruit under two brands only, all of which are points of the utmost importance in establishing a new fruit industry.

PUBLICATIONS OF THE EMPIRE MARKETING BOARD.

E.M.B.1.	AGRICULTURAL ECONOMICS IN THE EMPIRE. Report of a Committee appointed by the Empire Marketing Board	6*d*.	(7*d*.)
E.M.B.2.	TROPICAL AGRICULTURAL RESEARCH IN THE EMPIRE with special reference to Cacao, Sugar Cane, Cotton and Palms. By C. A. Barber, Sc.D., C.I.E. ..	1*s*. 6*d*.	(1*s*. 8*d*.)
	REPORTS ON DEVELOPMENT OF AGRICULTURE IN CERTAIN COLONIES. By H. C. Sampson, C.I.E., Royal Botanic Gardens, Kew :—		
E.M.B.3.	Trinidad	3*d*.	(4*d*.)
E.M.B.4.	British Guiana	9*d*.	(10*d*.)
E.M.B.5.	Leeward and Windward Islands and Barbados	6*d*.	(7*d*.)
E.M.B.6.	GEOPHYSICAL SURVEYING. Report of a Sub-Committee of the Committee of Civil Research	6*d*.	(7*d*.)
E.M.B.7.	THE CHEMISTRY OF WINE MAKING. A Report on Oenological Research. By J. T. Hewitt, M.A., D.Sc., Ph.D., F.R.S. ..	1*s*. 0*d*.	(1*s*. 2*d*.)
E.M.B.8.	GRASS AND FODDER CROP CONSERVATION IN TRANSPORTABLE FORM. Memorandum by A. N. Duckham, B.A., Dip. Agric. (Cantab.). Rowett Research Institute, Aberdeen	1*s*. 0*d*.	(1*s*. 2*d*.)

[*Continued*.

E.M.B. 14

THE

SURVEY METHOD OF RESEARCH IN FARM ECONOMICS

Memorandum prepared by
J. P. MAXTON, M.A., B.Sc.,
Agricultural Economics Research Institute, Oxford,
on behalf of the
AGRICULTURAL ECONOMICS COMMITTEE
of the
EMPIRE MARKETING BOARD.

JANUARY, 1929

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller.
1929.
Price 6*d.* Net.

70–221–14.

CONTENTS.

(34144) Wt. P.1556/1018 2,500 1/29 Harrow G.3

THE SURVEY METHOD OF RESEARCH IN FARM ECONOMICS.

PREFACE.

The Empire Marketing Board, in pursuance of its policy of stimulating research in agricultural economics, is undertaking the collection and dissemination of information likely to prove of interest to workers in this field. A preliminary report (E.M.B.1) has already been issued reviewing the scope and nature of agricultural economics.

The present Report outlines the main methods followed in farm management studies, and describes the procedure of the Survey Method and the significant information which may thereby be made available.

Efficient farm management is ultimately dependent upon a knowledge of the economics of the industry. This knowledge can only be built up by a careful and continuous analysis of reliable detail. Great importance attaches, therefore, to the study of the method by which research of the kind is carried out.

It is clear that while the study of agricultural economics in the Empire is still relatively undeveloped, there is a growing appreciation of the potential advantages to be derived from the development of the science along sound lines. The present report is issued in the hope that it may contribute in some measure to this development.

F. L. McDOUGALL.
Chairman of Agricultural Economics Committee.

Empire Marketing Board.
January, 1929.

(34144) A*

PART I.

INTRODUCTION.

THE need for investigation of a systematic kind into the business side of farm management is being increasingly emphasised in all countries. Research in the natural sciences has done immensely valuable work for farmers, but it has been already recognised in many countries that scientific investigation requires to be supplemented by economic research. The farmer does not view his farm as a laboratory for conducting experiments and for solving a large number of mechanical, physical and biological problems. The farm is a business unit in which the profit and loss account is the ultimate factor. Economic research is designed to investigate farming as a business.

There is an outstanding difference between the methods of economic research and those of scientific research. Scientific research works under laboratory conditions and conducts experiments under control. Economic research is almost entirely denied the use of the laboratory type of experiment. It is true that Colleges and Government Departments have conducted experimental farms on business lines, the results from which have proved of value. But natural and uncontrollable conditions of climate, etc., make it difficult to generalise from the economic results of one experimental farm to those of farming as a whole.

The inability to use the laboratory method is not a serious handicap to economic research, for it is the very essence of economic research that it should study farming as a "going concern" and not under any experimentally arranged conditions. To this end, it is necessary to record the facts of as many farms as possible and make systematic analysis of the facts. Economic research in farm management has been sufficiently well developed in some countries to warrant the claim that studies of the kind can help each farmer individually to improve the economic organisation of his farm and at the same time provide the foundation upon which agricultural policies may be built.

It is often suggested that while scientific research can improve farming by introducing new discoveries, the organisation of farming cannot be improved by economic research because successful

organisation depends entirely upon (1) soil and climate and (2) the individual ability of the farmer, or what is often called, the personal factor.

Professor G. F. Warren* expresses his opinion on this point of view as follows:—

> " It is frequently stated that success depends on the man. To some persons this seems a full and satisfactory explanation. But it explains nothing. It merely dodges the question. Success cannot come from merely being a genius. Success comes from doing certain things. The farmer does not sell himself. He sells milk, potatoes, hay, apples. It is such things as cost of production, amount sold, and price that determine his profits. The only way that a good farmer can express himself is by doing certain things. These things are fairly easy of analysis. If one farmer sprays his apples and another does not, it is the arsenic that kills the worms. Any other person can duplicate the result by spraying in the same way. If one farmer succeeds because he has better cows than another, this success can be duplicated. Certainly some persons will succeed where others fail, because they do things differently. Just what are the differences in method of procedure ? . . .
>
> " Many of the limiting factors are natural forces over which the farmer has little, if any, control. Other limiting factors that are not personality are prices, roads, freight rates, capital and the like. These limit what can be done by the best, as well as the poorest, farmer. With large numbers of records, it is possible to determine with a fair degree of accuracy the influence that each of the different factors has on profits. Any part of a farmer's success that is due to his acts can as readily be determined when large numbers of farms are studied."

Chief Methods of Investigation Compared.

The methods of economic research in farm management are based, therefore, upon the analysis of the organisation of individual farms. There are three main methods which have been used with success in different parts of the world. The three methods are not exclusive for they may, as will be seen, inter-act upon and supplement one another. They are (1) Cost Accounts, (2) Financial Accounts and (3) the Farm Management Survey. It is not intended to discuss here

* Cornell University Bulletin No. 349. " Some Important Factors for Success in General Farming and in Dairy Farming," page 659.

in detail the two first methods, but the outstanding features which mark them off from the third method may be noted.

(1) *Cost Accounting*, which has been widely used in England and America for a number of years, aims at examining each individual farm in as great detail as possible. Starting from the recognition of the fact that nearly every farm consists of more than one enterprise, records are kept throughout the year for each part of the farm so that at the end of each financial year the profit and loss of each enterprise on the farm can be calculated, as well as the profit and loss of the farm as a whole. It is possible, to a certain extent, therefore, to say which parts of the farm have contributed to the profitable outcome of the whole business and which have occasioned a loss. There is no need here to marshal together all the advantages and disadvantages of this method. The main advantage over other methods is the greater amount of detail obtained concerning each farm costed. The serious disadvantage of the method (especially where economic research is comparatively new) arises from the central facts that (1) it exacts regular attention from the farmer throughout the year in filling up his records and (2) it is expensive in the amount of accounting to be done by the department undertaking the work. For these two reasons it is not always easy to persuade a large number of farmers to keep the necessary records. Owing also to the extra expense which the addition of even one farm involves, only a limited number of accounts can be completed and analysed by research departments.

Under normal conditions, therefore, the method yields information upon only a comparatively few farms in an area and, as in the case of the experimental farm, it is difficult, owing to the diversity of farming conditions, to apply general conclusions from data obtained from so limited a number of sources.

(2) The method of *Financial Accounts* has been very widely adopted in some European countries. The data gathered by research departments consist of statements of annual receipts and expenses of as many farms as possible. The importance of this method in providing information upon the condition of farming, as well as certain useful facts relating to capital investment, labour, etc., need not be emphasised.

As compared with the method of cost accounting, financial accounts can provide information for a much larger number of farms. The information obtained has much less detail as to the management of each farm than the costing method yields, but a better statistical

sample is obtained of data relating to the main features of the farm business. As in the case of cost accounts, however, the criticism may be made that the farmers who are prepared to keep accounts are more progressive in the business side of their farming than the average, with the result that the study is not entirely representative. Whether, or not, this comment is justifiable, the willingness of farmers to keep accounts does set a limitation upon the wide extension of the research. All farmers do not keep accounts nor do all farmers who keep accounts keep them upon a uniform plan.

European countries operate the plan through farm accounting associations. Books are provided for the farmers and the balancing is done by clerks employed by the associations. It has been found to be difficult to organise associations of the kind in other countries and several years may elapse before a sufficient number of accounts are obtained to provide material for analysis. The survey method, on the contrary, does not depend upon farmers keeping exact accounts, nor upon the accounts, if they are kept, being upon a uniform plan.

(3) The arguments in favour of the *Survey Method* may be summed up as speed, cheapness and a much more comprehensive picture of economic conditions of farming. In a space of a few months a large number of survey records can be obtained, sufficient to form the sound basis of a description of farming conditions and to yield records for analysis, in the first year of working.

The *data* are obtained directly by a visit to every farmer in the area surveyed. If many of the farmers in the area keep accounts, information may be more quickly obtained and may be more precise. But it is claimed that even where the majority of the farmers base their information only upon the recollection of their year's transactions, the average of a group will be quite as reliable even if each individual farm record may not be as accurate as where accounts are kept. It is the group averages which are used in analysis by the survey method. Completed survey records cannot be obtained for every farm in the area, although the proportion of farmers willing and able to give complete information is surprisingly large, being usually over 90 per cent. Since, however, every farm is visited, the data, it is claimed, are likely to be more representative of the average conditions of the area than the data obtained by either cost or financial accounts. The survey method makes full use of financial accounts where these are available on farms which are being surveyed, but the method does not depend upon the existence of accounts.

PART II.

VALUE OF SURVEY METHOD.

The making of surveys of agriculture is probably as old as civilisation. Travellers view the farming of foreign countries and record their impressions. Writers of all centuries have written of the management of farms of their own country and among their neighbours. Many of them have been acute observers and faithful recorders. The distinction between these general surveys and the " survey method " as it is understood in agricultural economics, is that the former was, as a rule, based entirely upon personal observation. The weakness of personal observation for the purpose of modern economic study is discussed by Dr. Warren. " One of the most firmly established traits of human nature," he points out, " is to notice striking exceptions . . . . . The normal condition or usual thing is so common as to attract little attention ; the exceptions are conspicuous and attract attention and result in exactly the wrong conclusions." " Mere travel through a country, visiting farms or speaking to farmers in a region is likely to result in the memory of the striking and unusual. It in no way takes the place of statistical study. The very assurance that comes from observation sometimes makes persons with such experience the last to believe the truth of statistical study . . . ."*

The modern survey method, therefore, differs from the surveys of earlier centuries by the fact that it does not rely entirely upon individual observation and that its records are analysed statistically. The method outlined in the following pages owes more for its development to the work of Dr. G. F. Warren, of Cornell University, than to any other agricultural economist. The two bulletins of Cornell University quoted above together with another by Dr. Warren, although almost the earliest, may still be reckoned among the best of the few discussions of the method, the first by its spirited advocacy and the two others as showing the very great possibilities of the method in providing material for analysis of farming conditions and of farm management.†

The survey method admits of several modifications in practice, (1) according to the information required and (2) according to the

* Cornell University Bulletin 421, page 344.

† Bulletins of Cornell University, U.S.A., Nos. 344, 349 and 295.

period of time which the investigation is planned to cover. The general farm survey, or farm business study, covering all the main features of the whole farm business for the period of one year, has most universal application. Reference will be made later to the use of the survey method in the study of specific problems of farm management and also to the extension of the work to cover longer periods of time than a single year.

It must be noted that the survey method aims at limiting each study to a comparatively small area, within which the conditions are reasonably uniform, and at having the data and analysis complete for that area. Extension of the survey method over a wider and more diverse area, and ultimately over the country as a whole, is to be sought by multiplication of surveys rather than by the extension of one survey over the wider area.

Range of Knowledge to be obtained by the Method.

The most valuable feature is the wide range of knowledge of farming conditions which it can be expected to provide. The uses may be grouped under half-a-dozen heads.

1. General financial condition of the farming of the area surveyed.
2. Reliable information regarding the economic organisation of farming in the area surveyed.
3. The means of making a statistical analysis of the factors relating to successful farming in the area surveyed.
4. In certain circumstances, an approximate cost of production figure for the principal commodities produced.

Following from these, the survey method provides (5) a convenient opportunity of showing each individual farmer within the scope of the survey how the organisation of his farm compares (favourably or otherwise) with the average organisation of neighbouring farms, or even how his organisation compares with the average of a dozen or so of the most successful neighbouring farms, and (6) the means (if the surveys are conducted on uniform lines) of comparing the local conditions of farming with the conditions of more or less distant competing areas.

The results obtained from the survey along the lines of (1), (2) and (6) may be expected primarily to have most value in the guiding of public policies, either by governments or by farmers' associations but they have an important indirect influence upon the solution of the

management problems of the individual farmer. The results of the other uses, however, may be expected to help more directly individual farmers within the surveyed area to improve their farm management, by emphasising the most successful types of organisation in the area.

It is impossible to show the full value of the survey method in building up reliable data on each of these aspects without reproducing the complete report of a survey. It may be useful, however, to elaborate and illustrate the points mentioned from actual results.

1. *Financial Condition of Farming.*

An important part of economic study is the measure of prosperity of the industry at various times. The survey method provides an opportunity of obtaining information on this point. Examples of information of the kind obtained by the survey method for two districts may be quoted as follows :—

Table I.—*Showing percentage number of farms, in a defined area, making losses and profits of various amounts in 1913 and 1918. (U.S.A.).

Amount of Loss.	Amount of Profit.	Percentage No. of Farms.	
		1913.	1918.
More than 500 dollars	—	7	1
0–500 ,, ...	—	23	9
	0– 500 dollars	41	40
	501–1,000 ,, ...	19	32
	1,001–2,000 ,, ...	9	16
	Over 2,000 ,, ...	1	2

Note.—* In this and in subsequent tables, the selection for illustration has been made at random and the tables (only slightly modified) are given for the purpose of illustration only. For this reason, the sources have been deliberately withheld, the country only being given in brackets. *The figures in each case refer only to the defined area of one survey.* Acknowledgement is made here to the United States Department of Agriculture ; Farm Management Department of Cornell University, U.S.A. ; Farm Economics Department of Ontario Agricultural College ; and to the Agricultural Economics Research Institute, Oxford ; from whose publications these tables have been taken.

Table II.—Showing percentage number of farms, in a defined area, making losses and profits of various amounts. (U.S.A.).

Amount of Loss.	Amount of Profit.	Percentage No. of Farms.
More than 500 dollars	—	9·9
0–500 ,, ...	—	23·1
	0– 400 dollars	31·8
	401–1,000 ,, ...	20·4
	1,001–2,000 ,, ...	10·5
	Over 2,000 ,, ...	4·3

The type of information illustrated by these tables (always remembering that they refer only to the areas surveyed) offers opportunity for interesting study.

It should be noted that the "profits"* were not the direct estimates of the farmers themselves. The "profits" were calculated by the investigators from the complete data provided as to crops and stock, sales and expenses, etc., given in detail by the farmers.

2. *Reliable Information regarding the Economic Organisation of Farming.*

The most important, perhaps, of the uses of the survey method is to provide reliable descriptive information of the economic organisation of farming. As Dr. Warren has stated, agriculture has suffered to some extent from over-emphasis of the unusual and too little information on the normal conditions. The survey method provides the opportunity for counteracting this emphasis on the unusual.

* Discussion of measurement of profit is included in appendix.

A number of tables are given here to illustrate this type of information as obtained by the survey method :—

Table III.—Showing Capital invested in four types of farming in a defined area. (U.S.A.).

	Dairy.	Poultry.	Fruit.	Mixed.
Average size of farm ..	Acres. 134	Acres. 65	Acres. 46	Acres. 100
Average capital investment per farm ..	Dollars. 6,134	Dollars. 4,066	Dollars. 4,730	Dollars. 4,972
Capital per acre ..	46	63	103	50

Table IV.—Showing average distribution of capital on farms in a defined area. (U.S.A.).

	Real Estate.	Machinery.	Livestock.	Miscellaneous.
Average amount per farm	Dollars. 4,124	Dollars. 311	Dollars. 772	Dollars. 128
Per cent. of Total Capital	77	6	14	3

These illustrations have been torn from their context where the figures are more fully developed by other tables. They are sufficient, however, to show that this desirable information can be made available by the survey method.

Other illustrations of descriptive information of the kind are shown as follows:—

Table V.—Showing labour requirements according to type of farming. (Comparison from three surveys, England.)

	Acres worked per Man employed.	Acres worked per Work-horse used.
	Acres.	Acres.
Mixed farming ..	40	37
Milk	42	37
Grazing	77	91

The saving of man and horse requirements by pursuing a grass policy in these districts is immediately apparent from this table.

Table VI.—Showing percentage average distribution of farm expenses, in a defined area. (England).

Item of Expense.	Per cent. of Total Expenses.
Labour	22·18
Seeds	2·47
Fertiliser	1·81
Foods	9·12
Livestock	30·04
Rent and Rates	22·08
Tradesmen's Bills and other expenses	12·30
	100·00

Similarly, tables might be given illustrating all other aspects of the economic organisation of farming. Information relating to the sizes of farms ; to distribution of different kinds of livestock (and breeds) ; and to area of arable land and of different crops is obtained in the normal course of the survey, together with some indication of management. The following is an interesting illustration of general descriptive

data on the management of pig-breeding in a surveyed area of England :—

Table VII.—Showing the *number of herds* of each breed of sows kept and the boars with which they are mated (data from an area of 30 square miles, England).

Sows.	Boars.						
	Middle White.	Berkshire.	Large Black.	Gloucester Old Spots.	Tamworth.	Large White.	Total.
Large Black ..	17	4	9	3	—	1	34
Berkshire ..	6	9	3	—	1	—	19
Middle White ..	4	1	3	—	—	1	9
Tamworth ..	3	2	—	—	1	—	6
Large White ..	2	—	1	—	—	—	3
Gloucester Old Spot	4	2	—	—	—	—	6
Wessex	—	2	1	—	—	—	3
Essex	—	1	—	—	—	—	1
Crossbreds ..	11	11	2	2	—	—	26
Unknown Breeds	3	3	2	—	—	—	8
Total ..	50	35	21	5	2	2	115 herds.

Illustrations of this descriptive information obtained by the survey method on the economic organisation of farming could be multiplied indefinitely from various sources, covering a range of subjects which vary from capital investment to the size of farmers' families. These few illustrations, in fact, give a quite inadequate impression of the wealth of information relating to farm organisation given in the surveys from which these illustrations have been taken.

3. *Statistical Analysis of Factors relating to Successful Farming.*

The statistical analysis of the data—to show the influence of various factors of management upon one another—is, of course, the most specialised use of the survey method. It is also the use which

has been subjected to most criticism. In U.S.A., however, it has come through satisfactorily a prolonged controversy upon its validity.

Illustrations of the method, and of its efficacy, may be obtained by studying the effect of size of farm upon output and upon profits.

Table VIII.—Showing effect of size on the profits of farms in a defined area. (Canada).

Group according to size of Farm.	Average Labour Income* in each Group.	Average Labour Income on Best Farms in Group.
	Dollars.	Dollars.
Under 76 acres	498	1,534
76 to 90 ,, ...	818	1,758
91 ,, 110 ,, ...	802	1,770
111 ,, 135 ,, ...	1,018	1,965
136 ,, 160 ,, ...	948	1,926
161 ,, 185 ,, ...	1,213	2,475
186 ,, 225 ,, ...	1,339	2,585
Over 225 ,, ...	1,678	2,670

Note.—* Discussion of measurement of profit is included in appendix.

The influence of size of farm on profits has been shown by all survey reports, in North America at least, to be the predominant one. The following tables are given to illustrate how the survey method may be used to investigate further this question of the greater average profit from the larger farms.

Table IX.—Showing influence of size of farm on employment of manual and horse labour in a defined area. (England).

Size Group.	Arable Land per 100 Acres.	Persons employed per 100 Acres.	Draught Horses employed per 100 Acres.
	Acres.	No.	No.
Under 100	36·7	4·1	5·3
100–300	45·8	3·0	3·7
300–500	53·1	2·3	2·6
500–700	50·3	2·5	2·3
700–1,000	60·4	2·3	2·3

Table X.—Showing influence of size of farm on production per acre and production per person employed in a defined area. (England).

Size Group.	Sales per Acre.			Sales per Person employed.		
Acres.	£	s.	d.	£	s.	d.
Under 50	11	19	0	168	19	0
50–100	9	19	2	156	2	0
100–150	7	19	1	189	0	0
150–250	7	5	8	222	12	0
Over 250	8	4	4	316	19	0

Table XI.—Showing influence of size of farm on value of implement equipment per 100 acres in a defined area. (England).

Size Group.	Value.
Acres.	£
0– 49	328
50– 99	294
100–149	269
150–199	234
200–299	213
300–499	179
Over 500	139

These tables show that (in the areas to which they refer) while the small farm appears to make more productive use of each acre of land, it makes less profitable use of labour and requires proportionately higher capitalisation in machinery than the larger farms.

The size of farm is not the only important factor in farming which may be measured by the survey method. The following tables illustrate the use of the survey method to demonstrate the influence of crop yields ; of good livestock ; of the degree of specialisation and of heavy stocking per acre.

Table XII.—Showing influence of crop yields on labour income in a defined area. (Canada).

Crop Yields.*	Labour Income.	Crop Acres per Man.	Crop Acres per Horse.
	Dollars.	Acres.	Acres.
Under 81 per cent of average	624	34	14
81– 90 ,, ,, ,, ...	1,148	36	15
91–100 ,, ,, ,, ...	1,173	33	15
101–110 ,, ,, ,, ...	1,435	33	15
Over 110 ,, ,, ,, ...	1,510	32	15

The third and fourth columns of this table indicate that the better yields were obtained without adding proportionately to the supply of labour or horses.

Table XIII.—Showing influence of good livestock on labour income in a defined area. (Canada).

Quality of Live Stock.†	Labour Income.	Feed bought.	Labour hired per Farm.
	Dollars.	Dollars.	Dollars.
Under 71 per cent of average	14	206	425
71– 80 ,, ,, ,, ...	761	140	354
81– 90 ,, ,, ,, ...	948	231	425
91–100 ,, ,, ,, ...	1,310	233	446
101–110 ,, ,, ,, ...	1,498	266	417
111–120 ,, ,, ,, ...	1,610	296	368
121–130 ,, ,, ,, ...	1,872	338	549
Over 130 ,, ,, ,, ...	2,047	422	433

The second column indicates that, while extra feeding stuffs were purchased to obtain more returns from Livestock, the additional expense was warranted by the additional profits. The third column indicates that the expense of labour was not related to the greater returns.

* Crop Yields are based on a calculated figure called the Crop Index. Explanation of this calculation is given later.

† The quality of livestock is based upon Livestock Index, which is explained later.

In the opinion of Dr. Ladd, Director of Agricultural Extension in New York State, U.S.A., tables such as Tables XII and XIII have been used with great effect in the education of farmers towards crop and stock improvement, since the farmer understands them easily and has faith in them.

The following abbreviated tables give an example of some of the results of survey analysis which, while not necessarily conclusive, at least stimulate interest :—

Table XIV.—Showing " Specialisation—Does it pay ? " Data from defined area. (Canada).

Percentage of Total Farm Receipts from Dairy Herd.	Labour Income.
	Dollars.
Below 51 per cent ..	861
51– 60 ,, ..	1,384
61– 70 ,, ..	1,485
71– 80 ,, ..	1,285
81– 90 ,, ..	1,335
91–100 ,, ..	986

A table such as this requires corroboration over a period of years, as indicated later.

Table XV.—Showing "Number of Acres per Milch Cow for Greatest Profit." Data from defined area. (Canada).

Tillable Acres per Milch Cow.	Labour Income.	Sales per Cow.
	Dollars.	Dollars.
4 or less (Average 3·8) ..	1,790	116
4·1–5·0	1,438	121
5·1–6·0	1,413	114
6·1–7·0	1,183	113
7·1–8·0	935	97
Over 8·8 (Average 9·9) ..	780	97

The examination of relations between many other factors in production could be illustrated from surveys, e.g., relation of soil types to profits ; relation of distance from market to profits. The data derived by the survey method (due consideration being given to the statistical soundness of the analysis) admits of a very wide range of relationships being examined. Dr. Warren in one of the earliest surveys conducted by Cornell University, calculated the influence upon profits of such factors as the age and education of farmers, with quite remarkable results.

4. *The Use of the Survey Method to Arrive at Cost of Production of Commodities.*

This use is limited to special circumstances which arise where the type of farming is more or less specialised to the production of one commodity. The method is similar to that used in determining cost of production from a financial account of the farm, namely, to charge all expenses against the chief commodity. Receipts other than receipts from the chief commodity are credited to the account. An example may be taken of milk. All expenses on the farm for labour, foodstuffs, horses, etc., are charged against milk, even where some of these are expended upon poultry or potatoes for sale. The receipts from the other commodities such as eggs and potatoes are credited to the milk account and constitute, therefore, a deduction from the total expenses of milk production. The net expense is divided by the number of gallons produced, to arrive at cost per gallon. In other words, the farm is taken as a milk-producing business, the other commodities being treated as by-products. The method has not, of course, the refinement of the cost-accounting method and it may be of little value where two or more commodities are of equal importance in the sales of the farm ; but in the special circumstances of substantial specialisation, the figure arrived at may, in some respects, be more reliable from the farmer's viewpoint, since it treats the whole farm as a business unit. Results more comparable with cost account results can be obtained by the enterprise survey method referred to later.

5. *The Individual Farm Report.*

The individual farm report provides a convenient opportunity of showing each farmer within the scope of the survey how the organisation of his farm compares (favourably or otherwise) with the average

organisation of neighbouring farms. The value of the report may be considerable. It stimulates the farmer to look closely into the economic organisation of his farm. He can learn much himself from the report, and where agricultural advisers are available, the report provides a useful basis upon which to make adjustments of management. The lack of any digested record of the year's transactions is a serious hindrance to advisory work.

An example of the type of individual farm report issued by the Ontario Agricultural College is as follows :—

Table XVI.

From a Canadian Report.

INDIVIDUAL FARM REPORT—

For the Year ending February 28th, 1919.

Farm No......... Name.................... Address......................

Summary of Your Farm Business.

Total Capital		$12,610 00
Receipts : Crop Sales	$11 00	
Stock—milk sales, stock sales and natural increase	1,158 00	
Miscellaneous	184 00	
Increase in feed and supplies		1,353 00
Expenses : Current expenses, including labor, feed and seed, repairs, taxes, etc.	$477 00	
Depreciation (buildings and machinery)	187 00	
Decrease in feed and supplies	10 00	
		$674 00
Farm, " Net Revenue "		679 00
Interest on Capital at 5 per cent.		630 00
Labor Income		49 00

Table XVI—continued.

COMPARISON OF YOUR FARM WITH AVERAGE OF ALL OTHER FARMS THAT ARE OF SAME SIZE AS YOURS—IN TILLABLE AREA.

	Average of 35 Farms, 61–75 acres Tillable.	Your Farm.		Average of 35 Farms.	Your Farm.
Actual Acres	100	98	Labor Hired ..	$207	$126
Tillable Land—Acres	69	64	Depreciation		
Crops—Acres.. ..	45	34	(Buildings and		
Total Capital.. ..	$11,324	$12,610	Machinery) ..	$204	$187
Capital in Real Estate	$7,886	$10,000	Current Expenses	$674	$477
Capital in Buildings..	$3,034	$3,600	Gross Receipts ..	$2,049	$1,353
Capital in Machinery	$853	$572	*Labor Income* ..	$582	$49
Capital in Live Stock	$2,174	$1,859	Labor Income on		
Crop Acres per Man..	31	25	Seven Best Farms	$1,218	—
Crop Acres per Horse	12	13	Tillable Land Pas-		
Crops Sold	$584	$11	tured	—	47%
Feed Bought.. ..	$92	$27	Crop Index ..	100	95
			Live Stock Index	100	120

Causes of Low Labor Income :
(1) Too much tillable land in pasture.
(2) Not enough cash crops.
(3) Low crop acres per man.

6. *Comparative Advantages of Competing Areas.*

The last use of the survey method which need be mentioned here is that which is made of it to estimate the comparative methods and advantages of areas competing to produce the same commodity. This implies a more widespread development of the survey method than at present exists in most parts of the world, but its importance cannot be ignored. It may be expected, however, to lead to a more rapid dissemination of knowledge among farmers of national and world conditions of production of their commodities.

The outline and illustrations of the uses of the survey method display its merits. No claim is made that it is the perfect tool for the

solution of all the economic problems of agriculture. It is clear, however, that it has great value, especially in the initial stages of research, and that it offers wide scope for the future.

Modifications of Method.

Reference so far has been mainly to the general farm survey, or the farm business study, as it has been called, dealing with the data of one year. Obvious advantages attach to the repetition of the survey of the same area either annually for two or three years or at intervals of several years. Certain farming conditions do not change except very slowly, but other conditions, notably those which relate to prices, may fluctuate more or less quickly and they naturally affect the organisation of the farm business. The data for one year, therefore, have to be corroborated or revised periodically.

The survey method has also been used to very great advantage in what has been called the " enterprise survey ". This relates to the study of only one branch of the farm, as, for example, the growing of sugar beet, and the production of milk from tuberculin tested cows—to quote two recent instances in England. A further development of the enterprise survey is to combine the survey method with a limited costing method, in which case the data of the general farm business are obtained by the survey method while the production of one commodity is studied in more detail by cost records for that commodity alone.

To the various uses of the survey method here discussed, different degrees of importance will be attached according to the conditions of each country and each must adapt the method to its own uses. The very flexibility and adaptability of the method enhance its value for economic research.

PART III.

BRIEF OUTLINE OF PROCEDURE OF INVESTIGATION BY THE SURVEY METHOD.

The *data* used in the survey method are obtained by a single visit to every farmer within the projected scheme. The scheme may be taken to cover one geographical area or one type of farming. The investigator, by questioning, endeavours to ascertain from each farmer certain facts relating to his farm. The first step, therefore, is the compilation of a schedule of the information required for the purpose of the survey.

The common practice is to have the schedule in the form of a "field book", conveniently arranged for carrying about and having headings and spaces for all of the information which, it is expected, will be obtained from the farmer.

Importance of Preliminary Preparation of Schedule.

There are probably two main essentials of a good schedule. In the first place, the information sought must be pruned down to the necessary minimum. There is an abundance of interesting and useful information to be obtained on every farm, but both from the investigator's point of view and from the point of view of the farmer who is giving the information it is advantageous to reduce the number of questions to the smallest possible. As will be seen later, the number of questions asked, even when pruned down, will be large. Since the farmer, it must be remembered, is giving the information voluntarily, it is unfair to extend the inquisition any further than is necessary for the purpose in hand.

In the second place, the sequence of the questions should be arranged in the schedule in a logical manner. It is not always possible for the investigator to present the schedule to the farmer and fill in the answers on the spot. He must accommodate himself to the individual and be prepared to receive the information in the manner which best suits the farmer. The schedule must, therefore, be memorised by the investigator in order that no aspect of it may be missed in the end. It is easier to memorise a schedule which is systematically arranged.

The logical sequence required is that of making each question follow naturally from the answer to the previous question. It is not possible, of course, to carry out this completely, but it is worth taking pains

to do so as far as possible. So much depends for the success of the survey upon the alertness and honesty of the investigator that every detail which will aid him in his work should be considered.

The existence of a schedule, which is the bare skeleton of the information required, does not preclude the recording of the personal impressions of the investigator, nor of additional information where it is freely offered by the farmer. The schedule represents the minimum of information which must be obtained in statistical form if every record is to be of use in the analysis. Sufficient space, therefore, should be left in the " field book " for additional information which the farmer may care to give or which the investigator thinks it advantageous to record as throwing light upon some of the other *data* already recorded.

When a schedule is being used for the first time with a given type of farming, it will probably be found profitable to give it first a few days' trial to see whether it operates satisfactorily for the purpose in hand, before embarking upon the survey proper. For statistical reasons, very little change can be made in the schedule in the course of the survey.

The Data Required.

The facts which are wanted in the general farm surveys vary with the type of farming. Certain information such as size of farm, stock, acreage of crops, and so on, are common to nearly all surveys. The type of information asked for in the surveys conducted by the Agricultural Economics Research Institute, Oxford, is shown in the following summary of the schedule used :—

Name and address ; whether tenant or owner ; distances from nearest station and from market ; type of soil ; size of farm ; number of acres arable and number of acres grass. Rent and rates.

Area, yield, and sales or other method of disposal of each crop grown.

Numbers of each kind of livestock carried and sold.

Livestock produce (milk, butter, cheese, eggs, etc.), quantities produced and sold.

Labour, permanent and casual, with wages paid.

Fertilisers: kinds and quantities purchased.

Feeding stuffs: kinds and quantities purchased.

Seeds: kinds and quantities purchased.

Bills for miscellaneous expenses.

List of machinery and implements, including power machinery.

This summary alone of the data required indicates that even when the information sought is reduced to the minimum, it still involves an extensive list of questions.

In the U.S.A., where a great deal of investigation has been done by the survey method, a more or less standard form of " field book " has been used, sections not required in the study of a particular type of farming being left blank.

Obtaining the Interest of the Farmers.

It is desirable to endeavour to obtain the interest and co-operation of the farmers beforehand. Several ways have been used for this purpose and, of course, the method used must generally depend upon the district and upon the relations existing between the department carrying out the investigation and the farmers in the area. The purpose is probably best served by sending a letter to each farmer explaining the purpose of the investigation ; outlining the information which is being sought; giving assurance of the strict confidence in which the information is received ; and intimating the probable time of the visit of the investigator. Much explanation is thereby saved by the investigator when he arrives at the farm.

Organisation of Field Work.

The organising of the field work itself requires consideration according to the special circumstances of staff and of the district. The area has to be mapped out in order to save unnecessary travel and expense. The work may be carried out by one or by a pair of investigators visiting every farm, or by a team acting under the direct personal supervision of a director, every farm being visited by one of the team.

Transfer of Field Data.

At the close of each day's field work there are advantages in transferring the field records immediately to the more permanent record or " office sheet " as it may be called. This sheet is used later for analysis. It contains spaces not only for the *data* copied from the field book but also spaces for entering up the results of certain calculations which have to be made for the purpose of analysis. When copying in the *data* to the " office sheet " certain checks may be made of their accuracy. Where possible these checks are made roughly on

the farm at the time when the information is being sought. Any seeming discrepancies in the information can then be corrected or accounted for immediately by the farmer himself. It is not always possible, however, for the investigator to keep his mind on all points at the time but, if the checks are made each night, any inaccuracies may be remedied by letter or by a second visit.

Further importance attaches to the transference of *data* to the office sheet by the fact that farmers' answers are not always quite definite. The "field book," therefore, may contain certain particulars upon which the *data* are rather vague. It is essential that the *data* should be made precise on the "office sheet" since an indefinite statement cannot very usefully be rendered in a statistical analysis. A vague statement may be made sufficiently precise while the investigator's impressions of the farm are still fresh. If he cannot do so from his own impressions, the record must, of course, remain defective and will probably have to be discarded. Emphasis cannot be laid too strongly, therefore, upon the importance of transferring the *data* to a precise and clear form in the office sheet before the new day's impressions proceed to drive out those of the previous day.

Analysis of Records.

In practice, the first step in the digesting of the records is the making of certain calculations from the records themselves. Later analysis consists in grouping the records in various ways in an endeavour to see if natural relationships exist between the major factors of efficiency and the financial success of the farm.

Under normal conditions (see note in appendix on Profits), the financial profit or loss of the farmer may usually be taken as the most important and final test of the success or failure of the farming system. The main calculation, therefore, to be made on the survey records is an estimate of profit or loss.

As already noted the estimates of "profits" used in preceding tables were not the farmers' own statements of their profits. They were calculated from the detailed *data* received by the investigators. Valuations of capital, total receipts and total expenses were all made use of. Where farmers did not keep exact financial accounts, the resulting statements were bound to be estimates, but not mere guesses. It has been claimed that where a sufficiently large number

of records are obtained to form a good sample, the average of these estimates is very reliable.

While profits are the measure of the efficiency of the farms as a whole, it is necessary to relate them to the efficiency of the separate factors which are combined in farm management. Certain measures of efficiency of the factors in farm production are mentioned in earlier pages. They involve a large number of calculations to be made upon the records, some of the most important of which are illustrated here.

The most straightforward of the calculations are, of course, the summations of certain groups of figures to arrive at general totals, e.g. total capital investment, total cash sales, total cash payments, etc. These are often made at the time of the transfer of the data from " field book " to the " office sheet," since they serve a useful purpose in checking the record.

Examples of Some Useful Calculations.

There are, however, certain *data* which cannot be grouped nor used for comparison with other farms, without being first reduced to a common denominator. An example of this calculation is the reduction of the labour employed by the farm to the common term of " men equivalents." For example, one farm may employ two men for a full year ; another may employ one man and one woman full time for a year with another man employed casually. How do these farms compare as regards labour equipment ? In order to compare the amount of labour used it is convenient to use the term " men equivalents," or " labour units," and to reduce all paid labour to the terms of this unit. The table of conversion to men equivalents which has sometimes been used in England is as follows :—

1 man employed for a full year ..	1 man equivalent.
1 youth (16–18) employed for a full year	0·6 man equivalent.
1 woman, 1 boy } employed for a full year ..	0·5 ,, ,,

Part-time labour is reckoned according to this scale in proportion to the time worked.

Another example of conversion to a common unit is the use of " livestock units." Forty sheep and 10 cows cannot be added together except by conversion to a common unit. Where the stock carrying capacity of a farm is involved the scale used in England is to take

one sheep as the unit and to convert all other stock to the equivalent of " sheep units." The scale is as follows :—

1 cow or bullock over 3 years old	..	7 sheep units.
1 heifer or bullock under 3 years old	..	3·5 ,, ,,
1 horse over 3 years old	.. .. ..	7 ,, ,,
1 horse under 3 years old	.. .. ..	3·5 ,, ,,
1 pig (any age)	.. ..	1·5 ,, ,,
100 head of poultry	.. .. ..	7 ,, ,,

The scale may be expressed in cattle units :—

1 cow, bull, steer, horse	.. ..	1 unit.
2 calves, heifers, colts	.. ..	1 ,,
7 sheep or 14 lambs..	.. ..	1 ,,
5 hogs, 10 pigs	.. ..	1 ,,
100 chickens	.. ..	1 ,,

Stock which is held on the farm for only a part of the year, is calculated as part of one unit in proportion to the time occupied. The scale, it must be admitted, is somewhat, though not entirely, arbitrary. It is based roughly upon the demands which each class of stock makes upon the resources of the farm in grazing, foodstuffs, etc. The scale, however, without being final, has the merit of having been widely used. More delicate scales, however, are necessary in certain circumstances, and attempts are being made on these lines.

A third example of conversion to a common unit, is the reduction of the acreage of the farm. In many farms, the land varies from good arable land to rough pasture and even, in some cases, to woodlands which yield a certain amount of grazing for stock. For the reason that the proportions of each vary on different farms it has been thought necessary in the Ontario surveys to reduce the whole acreage of the farm to a common unit called " tillable " acres. The scale of conversion in such cases must of necessity be more crude even than the scales for " man equivalents " and " livestock units." The table of conversion used by Ontario Agricultural College is as follows, and in many cases this conversion, however rough and ready, may prove of considerable value :—

3 acres of rough land	.. ..	1 acre tillable land.
10 acres woods pastured	.. ..	1 ,, ,, ,,
1 acre in pasture ..	.. ..	1 ,, ,, ,,
1 acre in crops ..	.. ..	1 ,, ,, ,,

In some U.S.A. surveys, the whole is reduced to a term "crop acres," which is based upon estimates more exact than the above.

Crop and Live Stock Indices.

A somewhat different type of calculation used for making comparable the *data* of one farm with another is illustrated by what is called the " Livestock Index " and the " Crop Index." The purpose is to measure the relative efficiency of livestock and crop production respectively on each holding. The livestock index is calculated as follows :—

> " The gross receipts per animal unit on each farm is calculated. Then the average receipts per animal unit for the whole area is found. The farm showing receipts per animal unit exactly the same as the average figure for the area has a Livestock Index of 100. Likewise farms with receipts per animal unit 10 per cent. above or 10 per cent. below the average figure have, respectively, a Live Stock Index of 110 or 90." (Canadian Survey).

These calculations are given to illustrate some of the methods by which certain efficiency factors in farm production can be made comparable from one farm to another. They do not exhaust the computations of the data which may be necessary for certain purposes of analysis. Most of the others, however, which are necessary for both description and analysis require no explanations, e.g. the number of men employed ; the number of livestock ; the capital investment ; the gross sales, etc. may be shown per acre, or per man employed. The number of acres in crops may be calculated per man, or per acre, or per work horse. Other *data* are usefully rendered as percentages of a total, as, e.g. percentage capital in land and buildings ; percentage which each item of expense for labour, foodstuffs, etc., bears to the total expenses. Most of these have been used in the illustrations of the uses of the survey method given in preceding pages.

The calculations which are necessary vary with the nature of the farming and with any analysis which may be undertaken. Many, however, are so frequently used, that they may be made upon each record at the outset, before any grouping of the records is attempted.

It is impossible to outline the procedure of analysis of the survey records, since it varies so considerably with the factors which are to be correlated.

" The general problem is to find what relation exists between the magnitude of the various items and the efficiency of the farming. Farm management studies have shown that success in farming depends largely on the following factors : (1) type of land tenure, (2) type of farming, (3) magnitude of business and (4) the various factors of efficiency such as yield per acre, income per cow, adequacy and economy of equipment, diversity of business, productive work units per man and per horse, etc." (U.S.D.A. Circular, F.M.1).

The simplest method of correlation of these factors is by tabulation. Farms are grouped, according to the presence or absence, etc., of a certain factor, or according to the size of a particular factor. The average size of the other factor is calculated for each group. If some necessary connection exists between the two factors, the fact will be apparent by the tabulation in groups. As an example of the procedure a table used earlier for illustration showing the influence of size of farm upon " profits " may be repeated :—

Group according to Size of Farm.	Average Labour Income in each Group.
	Dollars.
Under 76 acres	498
76– 96 ,, ...	818
91–110 ,, ...	802
111–135 ,, ...	1,018
136–160 ,, ...	948
161–185 ,, ...	1,213
186–225 ,, ...	1,339
Over 225 ,, ...	1,678

The records, in this case, were sorted out into groups according to size of farm. The figures in the second column were obtained by adding together the " labor incomes " of all farms in each group and dividing by the number of farms. As the size of the farm increases, the average " labor income " tends to increase. An apparent connection, therefore, exists between the size of the farm and the profits which are likely to be made from the farm. The table can be expanded to show variations from the average within each group and the evidence has to be carefully sifted to test the accuracy of the conclusions drawn from the table.

Examples of some of the possible correlations have already been given. The tabulations are necessarily experimental, but roughly the same procedure is followed. A great deal of common sense, however, has to be exercised and the canons of statistical caution must be observed.

CONCLUSION.

The survey method by its comparative speed and cheapness ; by the comprehensive and unselected source of the data used ; and by its flexibility and adaptability to most widely varying conditions of farming, seems to warrant the careful consideration of all departments of economic research, but especially in agricultural areas where work of this character is comparatively undeveloped.

REFERENCES.

Cornell University N.Y. Bulletins.

No. 421. Some Important Factors for Success in general Farming and in Dairy Farming. G. F. Warren.

No. 344. Agricultural Surveys. G. F. Warren.

No. 295. An Agricultural Survey. G. F. Warren and Livermore.

U.S.D.A. Circular. F.M.I.

Suggestions Concerning Checking and tabulating Farm Management Survey Data.

U.S.D.A. Bulletin. No. 529.

The Validity of the Survey Method. Spillman.

Agricultural Economics Research Institute, Oxford.

The Work of the Institute. 2nd issue. C. S. Orwin.

Survey Method as an approach to the Study of Agricultural Economics (Agricultural Economics Society). A. Bridges.

APPENDIX.

NOTE ON THE MEASUREMENT OF PROFITABLE FARMING.

In view of the frequent use of a measurement of successful farming in the analysis of farm survey *data* and, indeed, in all methods of economic research, it is perhaps necessary to discuss briefly one or two aspects of the question.

" Profits " even in commerce and industry is a not very clearly defined term. In small, " one-man " businesses, the term " profits " refers to the " net returns " of the business, namely, the balance of gross receipts and gross expenses. The term, therefore, includes interest on capital invested in the business and payment to the owner for his management and perhaps actually for manual labour expended. In joint-stock enterprise, management is paid for in salaries and is, therefore, included in gross expenses. " Profits," therefore, refers in the latter case, to interest on capital only (ignoring the economists distinction between true interest and risk-bearing).

In farming, the same conditions exist as in the small one-man business organisation, but it is important for some purposes to be quite clear as to the nature of " profits."

Where the prosperity of the farmer alone is the matter to be considered, the " net returns " (or " profits " in that sense), is the important figure. Farm economists in U.S.A. and Canada, use the term " farm income " for this purpose. One cannot, however, ignore the fact that the range of capital invested in farming even within a small area, and especially between different types of farming, is a very wide one. The farmer with large capital invested in his farm is entitled to consider the relative advantage to himself of having that capital invested elsewhere, while he employs himself for a salary at some other trade.

For the purpose of showing this comparison, the common practice in U.S.A. and Canada has, therefore, been to deduct from the " net return " or " farm income " interest at a flat rate of 5 or 6 per cent. (being determined by the current rate of interest for farm mortgages in the district), on capital invested in the farm. The resulting figure has been given the name of " labor income " and refers to the payment for managerial and labour services given by the farmer. This is the figure used in the foregoing tables. It is obvious that with a large investment in a farm, a farmer may be making an actual profit on the year, while " labor income " may be negative. In the recent publication of one of the first New Zealand surveys, the term " wages capacity " was used to describe a similar figure.

It might be equally useful for some purposes to allow a deduction from " net return " or " farm income " of a salary for management and to show the resulting figure as interest on capital (on the lines of joint-stock practice).

Various other modifications might be useful in the method of expressing " profits." Difficulty, for example, arises in cases of tenancy. In Great Britain, the uniform implication of cash rent paid raises very little difficulty, but, in other countries where the financial conditions of tenancy vary from farm to farm in the same area, the precautions necessary to obtain uniformity of expression of financial returns of farms have to be taken.

It is perhaps unimportant which of the various figures is used to indicate prosperity of farms, provided that the meaning of the figure is adequately explained, and the calculations shown in such a way as to enable other measures to be calculated. The "net return," showing the balance of receipts and expenses is probably the most useful initial figure, other charges such as interest on loans or a manager's salary being shown separately as deductions from "net return." Other measures may then be calculated as desired.

The discussion, however, is not entirely closed by this means. There are difficulties inherent in farm conditions in all parts of the world for which allowances must be made.

By the survey method, it may reasonably be objected, the financial returns of only one year are given. The year may be a good one for farmers in the area or a bad one, and, as is well known, financial prosperity of farming can only be estimated by consideration of profits over a period of years. The accounting method, however, is open to the same criticism, and the survey method has the same opportunity of overcoming the difficulty, namely, by repeating surveys over a period. Reference has already been made to this aspect of the survey method. This objection to conclusions being drawn from one year's records must, however, be given prominence.

A further point of importance, however, requires mention. It has always proved a difficult thing to compare the profits of farming with the profits of other industries because, except in a somewhat arbitrary way, the values obtained from the farm by the farmer's household in the form of produce, use of house, and other less tangible things, are not readily measurable. On the other side of the account, the work contributed to the farm by children cannot always be taken into account. In commercial farms, i.e. farming for sale rather than for domestic use, these things may be proportionately quite small. The "farm income," however, does not, for these reasons always quite indicate the measure of prosperity which the farmer enjoys.

In peasant and native agriculture, these circumstances become of first consideration. Almost the whole production of the farm may be utilised for the purpose of feeding and maintaining the family, only a small proportion of the output being sold for cash. Under these conditions, the final test of success cannot usefully be the financial profit and loss as measured by money receipts and expenses. Some other test would have to be devised which would be more in keeping with the circumstances.

Finally, there are circumstances in which, from the national viewpoint, the financial profit or loss of individual farmers cannot be the final test of good farming. Conditions of war in a country such as Britain may, for the period, emphasise the need for the largest possible output of foodstuffs. It is obvious, of course, that since prices may normally rise with demand upon the restricted supply under these conditions, the largest output is usually synonymous with the largest profit, but, from the national point of view, it is the maximum output of food that at such times becomes of first importance. This aspect had an important influence upon some of the post-war economic writings on agriculture in Britain, and the tests of "output per acre" and "output per man" were strongly stressed.

Under normal conditions of commercial farming, however, the financial "net return" or "farm income," with its modifications of "labor income," etc., may usually be taken as the most important test of the success or failure of the farming system.

THE EMPIRE MARKETING BOARD.

The Secretary of State for Dominion Affairs and for the Colonies.
(The Rt. Hon. L. S. Amery, M.P.) (*Chairman*).

The Parliamentary Under-Secretary of State for the Colonies.
(The Rt. Hon. W. G. A. Ormsby-Gore, M.P.) (*Vice-Chairman*).

The Financial Secretary to the Treasury.
(Mr. A. M. Samuel, M.P.)

The Parliamentary Secretary to the Ministry of Agriculture and Fisheries.
(The Rt. Hon. The Earl of Stradbroke, K.C.M.G., C.B.)

The Parliamentary Under-Secretary of State for Scotland.
(Major Walter E. Elliot, M.C., M.P.)

The Rt. Hon. J. H. Thomas, M.P.

Sir Archibald Sinclair, Bart, C.M.G., M.P.

Sir Edward Crowe, C.M.G.
(Comptroller-General of the Department of Overseas Trade.)

Sir Thomas Allen
Sir William Crawford, K.B.E. } (Great Britain).

Mr. W. A. Wilson (Canada).

Mr. F. L. McDougall, C.M.G. (Australia).

Mr. R. S. Forsyth (New Zealand).

Mr. J. Dimond (Union of South Africa).

Mr. J. W. Dulanty, C.B., C.B.E. (Irish Free State).

Sir Francis Newton, K.C.M.G., C.V.O. (Southern Rhodesia).

Mr. H. A. F. Lindsay, C.I.E., C.B.E. (India).

Sir Edward Davson, Bart. (Colonies and Protectorates).

Mr. S. G. Tallents, C.B., C.B.E. (*Secretary*).

Mr. E. M. H. Lloyd (*Assistant Secretary*).

AGRICULTURAL ECONOMICS COMMITTEE.

Mr. F. L. McDougall, C.M.G. (*Chairman.*)
(Representative of Australia on the Empire Marketing Board).

Sir David Chadwick, C.S.I., C.I.E.
(Imperial Economic Committee).

Mr. R. R. Enfield.
(Ministry of Agriculture and Fisheries).

Mr. R. B. Forrester.
(London School of Economics, University of London).

Sir Robert Greig, M.C.
(Board of Agriculture for Scotland).

Mr. J. B. Guild, M.B.E.
(National Farmers' Union).

Mr. H. A. F. Lindsay, C.I.E., C.B.E., I.C.S.
(Representative of India on the Empire Marketing Board).

Mr. E. M. H. Lloyd.
(Empire Marketing Board).

Mr. J. P. Maxton.
(Agricultural Economics Research Institute, University of Oxford).

Mr. C. S. Orwin.
(Agricultural Economics Research Institute, University of Oxford).

Mr. J. A. Venn.
(Department of Agriculture, University of Cambridge).

Mr. Karl Walter.
(Horace Plunkett Foundation).

Mr. G. M. Dykes (*Secretary*).

E.M.B. 15.

ORANGES

WORLD PRODUCTION AND TRADE

MEMORANDUM PREPARED IN THE STATISTICS AND INTELLIGENCE BRANCH OF THE EMPIRE MARKETING BOARD

APRIL, 1929

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller

1929.
Price 1*s.* 0*d.* Net.

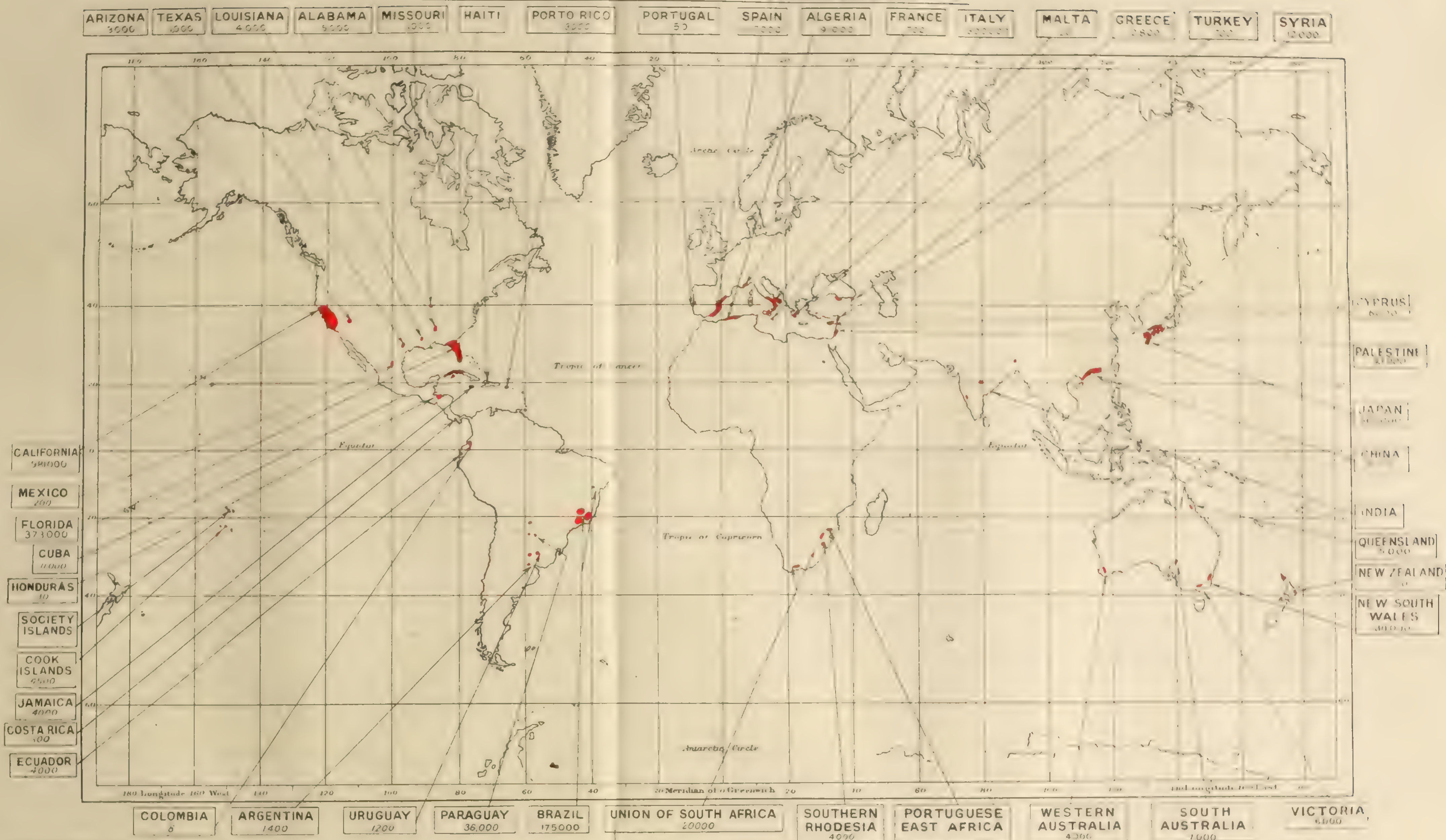
70-221-15.

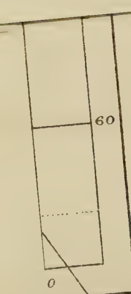
TABLE OF CONTENTS

(34803) Wt. P1917/505 2500 4/29 Harrow G.3.

ORANGE-GROWING COUNTRIES OF THE WORLD

PRODUCTION OR EXPORTS IN TONS





CTORIA
6,000

..M S O., Cr. Lith

FOREWORD.

THE Empire Marketing Board has received applications from time to time from certain Colonies for assistance in establishing or developing an orange export industry. At the same time the rapid development of the world's orange production and trade during the last few years and the increasing difficulty which producers in some countries find in disposing of their crops at remunerative prices, have drawn attention to the question whether orange production may possibly be in danger of developing too rapidly.

The Fruits Committee and the Agricultural Economics Committee of the Board accordingly suggested that the Board's Statistics and Intelligence Branch should undertake a statistical survey of the production and consumption of oranges, in order to serve as some guide in estimating the future possibilities of the orange market.

The memorandum deals only with the quantitative aspect of production and trade; the question of quality, important though it is, is introduced only in so far as it affects, or is likely in future to affect, the volume of oranges entering world trade. No attempt is made to consider such questions as the economics of production, market prices and transport costs. While these all play their part in influencing the exportable surplus in different countries, or in the import requirements of non-producing countries, they are matters for more local and intensive study than can be contemplated in this paper, which in essence consists only of a statistical record of the orange trade of recent years, and an indication of the general trend of production and consumption.

Certain minor difficulties have been encountered. In most countries the classification of oranges in trade returns does not differentiate between mandarines and close skinned oranges. Where such differentiation is made the separate figures have been shown; but the point is of minor importance.

A more important obstacle to complete records is the failure of some countries to separate lemons from oranges in their trade returns. These two fruits are only in part competitive and the classification of the two in one group, where it occurs, reduces the value of the figures.

Statistics of production and trade are given in a variety of measures—cwts., metric quintals, boxes, bushels and counts are all used, and there is no invariable factor for the conversion of boxes and counts into cwt. Generally in these tables the standard box has been taken as equivalent to 78 lb., the Spanish half case as about one cwt., and where trade returns show exports by number only, a rough conversion, varying with the type of orange, has been attempted in the text for the sake of comparison.

STATISTICS AND INTELLIGENCE BRANCH,
EMPIRE MARKETING BOARD.

FEBRUARY, 1929.

ORANGES—WORLD PRODUCTION AND TRADE

INTRODUCTION.

1. Almost the whole of the world's orange production is found between latitudes 20° and 40°, in both northern and southern hemispheres. In the northern hemisphere production in both Spain and Italy extends slightly north of 40°, and there is a small production of oranges and mandarines in southern France, while just south of 20° there is the production, small in relation to the world total, of Jamaica, Porto Rico, Honduras and India. In the southern hemisphere, the only production south of 40° is the insignificant output in the South Island of New Zealand, while slightly north of 20° occurs the small production of Bahia (Brazil), Queensland and the Society Islands. Nearer the equator, oranges are produced in small quantities in Costa Rica, Colombia, Ecuador and tropical Africa, but rather over 99 out of every 100 oranges grown in the world are within the limits of latitude 20° and 40°.

2. The principal producers of oranges are the United States, Spain, Japan and Italy. The United States now vies with Spain in output, and in 1926–27 had the greater crop, but in that year the Spanish production was severely reduced by frost. In each of these countries during the past few years the output has been over one million tons per annum.

3. Italy and Japan compete for third place, but are far behind either Spain or the United States. There are many other countries producing considerable quantities, but in many cases production figures are not obtainable, and none of them are such large producers as the above four, which together produce fully three-quarters of the world's total output.

4. Most of the United States production is consumed within that country and Spain is easily the world's greatest exporter, its exports being roughly twice as great as those of all other exporting countries combined. Italy takes second place with a quantity about one-fifth that of Spain, and the United States is third, while Palestine is of growing importance, being now not far behind the United States. Smaller quantities are exported by the other producers, the chief contributors to world supplies being the Union of South Africa, Australia, Algeria, Japan, Syria, Cuba, Porto Rico, China, and the countries of South America.

5. The principal markets for exported oranges are in Europe. The United Kingdom takes fully one-third of the oranges entering world trade, Germany is second, importing in 1927 about one-half the quantity of the United Kingdom, while other important markets in Europe are France, Belgium, Holland, Poland, Czechoslovakia, Switzerland, Norway, Sweden, Hungary, Denmark, Irish Free State, and Rumania.

6. The following pages deal with the various producing countries, and with the chief European countries which comprise the markets for the bulk of the world's surplus production.

PRODUCTION AND EXPORT.

United States.

7. One of the two greatest growers of oranges in the world is the United States, which produced an average of over 34 million boxes annually during the years 1922 to 1926. The details of production in the various States during the five years ending 1927, are shown in the following table :—

TABLE I.—*Production of Oranges (including tangerines) in the United States* (1923–1927).

(In thousands of cwt.)

State.	1922–23.	1923–24.	1924–25.	1925–26.	1926–27.
California	14,688	16,084	12,604	16,853	19,619
Florida	7,104	8,984	8,080	6,337	7,452
Alabama	244	314	1	139	104
Arizona	56	60	42	60	52
Louisiana	42	52	52	70	87
Missouri	31	38	—	19	29
Texas	3	4	8	7	14
Total	22,168	25,536	20,787	23,485	27,357

8. Throughout the orange producing States, the number of orange trees in full bearing is increasing ; in Florida the number of trees increased more than 100 per cent. between the years 1920 and 1926. The number of orange trees of bearing age for various years in Florida and California is shown below :—

TABLE II.—*Number of Orange and Tangerine Trees of Bearing Age in Florida and California.*

(Thousands of trees.)

Year.	Florida.	California.
1889	2,725	1,154
1899	2,553	5,649
1909	2,790	6,619
1919	3,684	10,800
1922	5,125	16,456
1923	6,025	16,785
1924	7,306	17,114
1925	7,601	—
1926	8,546	—

9. The acreage of orange trees in bearing in California increased by 50 per cent. in the last eleven years, that is from 124,000 acres in 1917 to 187,000 acres in 1928, while the non-bearing acreage is now about 22,500 acres. According to official forecasts respecting the next few years, the bearing acreage is likely to remain stationary at about 187,000 acres, although production has probably not yet reached its maximum, as a considerable proportion of the area is not yet in full bearing. But it is significant that the 22,500 acres not in bearing in California consist for the most part of Valencias, the season for which runs from April to October, indicating an increasing production of summer oranges in future years.

10. But while only a moderate expansion in the productive capacity of Californian orange groves is to be looked for during the next few years, in Florida developments are likely to be much more pronounced.

11. Between 1919 and 1927 the bearing acreage of oranges in Florida increased by 143 per cent., from 53,000 acres to 128,000 acres, and the total acreage, including non-bearing, had reached 208,500 acres by 1927, or almost exactly the orange acreage of California at the present time. But of the Florida acreage no less than 80,000 acres, or 38½ per cent., were not yet in bearing in 1927, and a substantial proportion of the remainder had not reached full bearing.

12. An orange tree in Florida comes into bearing in its fifth year, so that by 1932, the whole of the 208,000 acres under oranges in 1927 should be in bearing, less only such areas as are taken out of production or are not allowed to reach production. According to "An Economic Survey of the Orange Industry of California," recently issued by the University of California, the net increase in bearing acreage in Florida by 1932 is estimated at 64,000 acres, or 50 per cent. on the 1927 figure.

13. The whole evidence goes to show that the productive capacity of these two States (other States are relatively unimportant) is likely to increase substantially within the next five years. The increase in the case of California will be only moderate, the chief factors to be considered being the greater average yield per tree as more trees come into or approach full bearing, and a possible expansion of bearing acreage as the present non-bearing acreage comes into bearing.

14. In Florida, however, there is an additional factor of importance. During the past four years (from 1924/5 to 1927/8) orange yields in that State have been below normal because of the adverse influence of the real estate boom, frost and drought.

15. These conditions cannot be expected to continue, and if yields per acre within the next four years recover only one half of the loss since 1924–25, annual production may easily reach 20 million boxes by 1932–33, and in a good year might reach 25 million boxes, as compared with the $10\frac{3}{4}$ million boxes in 1926–27 and 10 million boxes in 1927–28. With California producing over 30 million boxes, a total of over 55 million boxes, or 40 per cent. more than the 1926–27 figure, is possible within the next five years, although much depends upon the rapidity with which groves in Florida recover from the effects of the real estate boom, and upon the area which must be regarded as almost permanently lost to orange cultivation.

16. Production in the United States has recently increased much faster than the population and this disparity is likely to continue during the next few years. Despite the expedients which are being tried with the object of stimulating the domestic consumption of oranges and orange products, it is not improbable that the exportable surplus will increase also. Most of the United States oranges are at present consumed within the country and the number exported is small by comparison with the number produced, and with the exports from Spain. Of the 40 million boxes produced in 1926–27 less than 4 million were exported, although this represents an increase of

about 1 million boxes over the previous season. The bulk of the exports go to Canada, but between 1925–26 and 1926–27 exports to the United Kingdom nearly trebled, and this increase is especially important from the Empire standpoint inasmuch as exports to the United Kingdom market are mainly in the summer months when South African supplies are coming forward.

17. In the following table are shown United States production figures for the three years ended 1927 and exports during the corresponding years. It should be noted that the Californian citrus crop year runs from 1st November to 31st October, and those of other States from 1st September to 31st August. The export season has been taken as from 1st November to 31st October, as California at present produces over 70 per cent. of United States oranges, and the bulk of the oranges exported are Californian.

TABLE III.—*U.S.A. Production and Exports of Oranges, 1924–25—1926–27.*

	1924–25.	1925–26.	1926–27.
Production .. .. .. 000 boxes	29,850	33,220	39,280
Exports .. .. .. ,,	1,978	2,628	3,612
Percentage of exports to total production	6·6	7·7	9·2
Exports to—			
United Kingdom .. 000 boxes	42	218	619
Canada .. .. .. ,,	1,812	2,240	2,684
Other countries .. .. ,,	124	170	309
Percentage of total exports sent to—			
United Kingdom .. per cent.	2·1	8·3	17·2
Canada .. .. .. ,,	91·6	85·2	74·3
Other countries .. .. ,,	6·3	6·5	8·5

18. Owing to poor weather conditions, the 1927–28 orange crop in Florida and California combined was reduced to about the 1925–26 figures, and exports were correspondingly reduced during the past twelve months. But the above table shows that with a satisfactory crop the United States has already a large exportable surplus apart from the quantity taken by Canada.

19. With so great a domestic market it is impossible to foretell what the distribution of the United States orange crop may be in four years' time, if production reaches 55 million boxes. Consumption is increasing rapidly, but with a crop 40 per cent. in excess of the

record of 1926–27, consumption would need to show a more than commensurate increase if the exportable surplus were not to become unwieldy. In the case of apples, from 11 to 12 per cent. of the commercial crop is exported annually with fair regularity. If the position in regard to apples is paralleled by oranges, exports would reach between 6 million and 6½ million boxes in a crop of 55 million boxes, and it is doubtful whether Canada would be able to absorb more than one-half this quantity, leaving some 3 million boxes for other markets. But a variation of only 2 per cent. in domestic consumption would alter the exportable surplus by a million boxes.

20. The bulk of the United States orange crop is marketed from November to May, the only oranges marketed from June to October being the Valencia oranges of Southern California ; and (in October) the first shipments of the Florida crop. The Florida season extends from October to June with December as a peak month ; central California (of relatively small importance) ships Navels in November and December and Valencias in April and May ; and the southern Californian Navel crop runs from November to April or May. Table IV below shows orange movements by months over the four years 1924–25 to 1927–28.

TABLE IV.—*Movement to Market of United States Oranges.*

Month.	1924–25.	1925–26.	1926–27.	1927–28.
	Carloads.	Carloads.	Carloads.	Carloads.
November	8,511	7,023	6,342	4,677
December	8,797	7,877	9,877	9,736
January	8,382	6,537	7,988	6,349
February	6,598	6,243	7,606	6,006
March	7,035	7,904	8,990	7,055
April	5,599	8,098	9,296	6,036
May	4,808	5,683	7,172	5,499
June	3,416	4,183	5,168	2,920
July	2,031	4,163	4,084	3,027
August	1,740	3,210	3,666	2,764
September	1,726	3,044	3,265	2,755
October	1,165	3,183	3,296	2,846
Total	59,808	67,148	76,750	59,670
Percentage, 5 months, June–October	*16·8%*	*26·5%*	*25·4%*	*24·0%*

21. Only about one-quarter of the United States orange crop is marketed during the five months June to October, and the prospective increase in the output is likely to enhance this disparity. Estimates of increasing production are based partly upon a recovery in yields in Florida, which will mainly affect supplies from November to April, and partly upon the increasing bearing acreage in Florida, which will result in larger supplies in the same period, but especially from February to April, as the non-bearing acreage consists largely of Valencias. A slight increase in the relative bearing acreage of Valencias as compared with Navels in California is in prospect, but this is of much less importance than the prospective increase in Florida production.

TABLE V.—*Exports of Oranges from the United States by Months.*

Month.	To United Kingdom.	To Canada.	To other Countries.	Total Exports.
	Thousand boxes.	Thousand boxes.	Thousand boxes.	Thousand boxes.
1926–27.				
November	10	122	16	148
December	7	294	20	321
January	12	204	17	233
February	19	189	24	232
March	21	280	32	333
April	72	286	31	389
May	53	342	51	446
June	97	308	44	449
July..	122	215	39	376
August	83	202	13	298
September	77	129	11	217
October	46	112	11	169
1927–28.				
November	1	78	9	88
December	1	303	27	331
January	4	188	23	215
February	8	216	10	234
March	6	264	25	295
April	15	220	21	256
May	20	236	31	287
June	18	185	18	221
July	15	140	20	175
August	27	148	11	186
September	22	111	12	145
October	6	94	8	108

22. Exports from the United States to Canada continue throughout the year, but from November to March or April, when European orange crops are being marketed, only small quantities are shipped to Europe. Table V shows exports by months during the two years commencing November, 1926.

23. The ability of European markets to absorb large quantities of United States oranges between November and April is limited on account of the large supplies of comparatively cheap Mediterranean fruit during that season, but it is precisely during those months that United States production is likely to show the greatest increase.

Spain.

24. Spain is second only to the United States among the orange-producing countries of the world, the total crop averaging about 22,000,000 cwt. A large number of varieties are grown, but in general the fruit is classified as " Whites," " Bloods " and " Blood Ovals," together with bitter oranges and mandarines. Over 70 per cent. of the total area of oranges is in the two provinces of Valencia and Castellon, covering a long strip of land on the Mediterranean coast from Denia in the north to Vinaroz in the south, about 150 miles long and 10 to 20 miles wide. The remaining production in Spain is in Murcia, Almeria and Malaga on the same coast, and Seville inland, where the famous bitter oranges are produced.

25. In Table VI are shown the total area and production of oranges for the past three years, according to statistics issued by the Agronomic Council at Madrid.

TABLE VI.—*Area and Production of Oranges in Spain.*

Year.	Area (acres).	Production (cwt.).
1925–26	131,800	23,060,000
1926–27	133,100	20,553,000
1927–28	146,000	22,343,000

26. The market for Spanish oranges is the continent of Europe, the quantity sent to other parts of the world being negligible. More than half of the exports in 1926 were consigned to the United Kingdom

while large quantities were sent to France and Germany, and substantial amounts to Belgium, Holland, Norway, Denmark and Sweden. The following table shows Spanish orange exports to various countries during a number of recent years.

TABLE VII.—*Exports of Oranges from Spain.*

Consigned to	1920.	1921.	1924.	1925.	1926.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Great Britain	4,012	5,467	6,446	6,726	7,117
Germany	—	—	1,778	2,369	1,995
France	438	1,342	1,608	2,468	2,609
Norway	130	115	201	239	231
Belgium	189	488	986	1,004	977
Holland	117	590	1,300	995	870
Denmark	68	147	184	142	121
Sweden	80	69	87	105	99
United States	6	3	5	5	1
Argentine	2	2	2	5	—
Poland	—	—	11	—	—
Finland	—	—	—	—	46
Other countries	35	322	5	9	48
Total	5,077	8,545	12,613	14,067	14,114

27. It will be observed that total exports are increasing, the 1926 total figure being as much as 180 per cent. in excess of that for 1920. The United Kingdom and French markets are absorbing a steadily increasing amount and Germany has again become a purchaser during recent years. During last season (1927–28), total exports amounted to nearly 16,000,000 cwt., of which 6,800,000 cwt. were shipped to the United Kingdom, 6,000,000 cwt. to markets in Northern Europe, while 3,000,000 cwt. were sent overland across the French border.

28. There is some apparent discrepancy between the figures of production and export. Owing to high internal transport costs the consumption of oranges in the non-orange producing districts of Spain is very small, and total Spanish consumption is generally

understood to form only a small percentage of the quantity produced. The figures in the above tables, however, indicate an export of only 70 per cent. of production, and it is somewhat doubtful whether the balance can be accounted for by domestic consumption and waste.

29. Figures of new plantings of oranges in Spain are not available, but it is understood that there have been extensive plantings in recent years, and this information is borne out by the figures of orange acreage given in Table VI, which indicate an increase in area of more than 10 per cent. in the past two years. Indefinite as the available information is, it suggests that exports of oranges from Spain are likely to increase, and where export is already so large in relation to exports from other sources, even a small proportionate increase becomes of prime importance.

30. Shipments of Spanish oranges commence in November and continue to be heavy until May or June, after which comparatively few are exported. Thus the figures for calendar years include the latter part of one season and the first part of another. The following table shows the exports by principal countries in each of the quarters of the year 1926.

TABLE VIII.—*Exports of Oranges from Spain*, 1926.

Consigned to	January to March.	April to June.	July to September.	October to December.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Great Britain	3,328	2,286	467	1,036
France	1,426	535	7	642
Germany	1,271	445	21	258
Belgium	674	186	29	88
Holland	361	338	117	53
Norway	142	45	33	10
Sweden	62	26	2	9
Denmark	94	24	Nil	4
Other countries	47	24	1	23
Total	7,405	3,909	677	2,123

31. The oranges exported are generally graded to size, and the package most commonly used is the half-case of about 110 lb., the number to the half-case varying from 240 to 504. In 1925–26 and again in 1926–27, following frosts in December, export was prohibited for a short period, and a system of inspection was inaugurated to prevent the shipment of frost-damaged fruit. Generally, however, until this year there was little regulation as regards quality or condition of fruit exported, and while the bulk of the fruit shipped to the chief consuming markets was of good quality, arrivals towards the end of the season were frequently in indifferent condition. With the commencement of the 1928–29 season, however, a system of government inspection has been inaugurated to prevent the export of fruit considered unsuitable for consuming markets.

32. The overwhelming importance of Spain as a source of cheap oranges for the large consuming markets of Europe is undeniable and there is very little prospect of her pre-eminence being challenged. Costs of production and marketing are low, transport costs to consuming markets are small, and it has been estimated that by improvements in methods of cultivation the output could be very greatly increased.

33. The end of the Spanish season in June overlaps the beginning of the South African season, but the variable and often poor condition of the late season arrivals minimises the competition between the fruits from the two countries. If Spain is able to develop successfully the production of later varieties of oranges, and so extend her season, the competition might well become formidable. But although a few years ago there was a good deal of interest, especially in the Murcia district, in the Verna Imperial variety, which is avilable for shipment from June onwards, this interest has now waned.

Italy.

34. Italy is the third largest grower of oranges supplying fruit to European markets although production is far below that of the United States and Spain. According to the Banca Nazionale dell' Agricultura, the crop for 1926–27 amounted to 266,000 tons and that of mandarines

to 34,000 tons, as against an average for the years 1921–25 of 271,000 tons of oranges and 24,000 tons of mandarines. The Notizie Periodiche di Statistica Agraria gives the total production of oranges in 1925 at 260,000 tons, over 50 per cent. of which were produced in Sicily, and of mandarines at 27,000 tons, the details for the various provinces being as follows :—

TABLE IX.—*Production of Oranges and Mandarines in Italy*, 1925.

	Oranges.	Mandarines.
	000 cwt.	000 cwt.
Sicily	2,921	313
Calabria	1,488	98
Campania	593	100
Apalia	89	—
Sardinia	108	20
Total	5,199	531

35. The area under oranges is reported to be extending but slowly, if at all, and no substantial increase in production is to be expected, at any rate in the near future. In fact, production in recent years has tended to decrease, although new plantings, when they are made, are mainly of varieties suitable for export.

36. Italian exports for the four years 1924 to 1927, were greatly in excess of those for the two previous years, but the increase is mainly accounted for by the larger quantities taken by Germany. Average exports for the three years 1925–27, amounted to 142,000 tons per annum, as compared with an average of 118,000 tons per annum for the five years, 1909–13.

37. The following table shows the exports to principal countries of consignment for the years 1923–27. Germany is by far the greatest buyer, although considerable quantities are sent to other European countries.

TABLE X.—*Distribution of Exports of Oranges and Mandarines from Italy*, 1923–27.

Consigned to	1923.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Germany	333	1,195	1,406	1,088	1,399
Austria	190	316	468	397	415
Switzerland	231	233	205	123	149
Hungary	1	41	170	238	261
Czechoslovakia	82	106	139	187	195
France	494	137	75	27	59
Yugo-Slavia	57	62	69	118	119
United Kingdom	49	46	41	150	72
Poland	7	93	64	102	108
Sweden	31	50	42	87	123
Denmark	24	38	29	35	34
Rumania	27	40	12	17	31
Malta	17	—	23	25	19
Belgium	6	8	56	4	16
Other countries	52	64	41	72	71
	1,601	2,429	2,840	2,670	3,071

38. The principal exporting months are from December to June, and the quantity consigned from July to November is small. The following table shows the monthly exports for 1926 and 1927 :—

TABLE XI.—*Exports of Oranges and Mandarines from Italy*.

Month.	1926.	1927.
	000 cwt.	000 cwt.
January	387	499
February	514	847
March	722	742
April	457	489
May	263	262
June	66	31
July	3	2
August	2	—
September	1	—
October	—	—
November	25	44
December	230	155
Total	2,670	3,071

39. Several varieties of oranges are grown in Italy, the two main types being Sicilian " bloods " and " ovals." In addition there is the appreciable production of mandarines (the Sicilian mandarine is said to be the largest in the world) and a relatively small output of bitter oranges.

40. Orange growing in Italy has in the past been unorganised and no restrictions were imposed upon exports in respect of quality or grading. The export industry is now being put on a sounder basis, and the National Institute for Exportation is empowered to grant licences for the use of a national mark by exporters complying with certain prescribed requirements as regards size, quality and packages. While this may at first tend to reduce the volume of shipments, it is not certain to do so, as the use of the mark is not compulsory. But it should certainly tend to improve the general quality of the oranges exported, and the increased returns gained thereby may ultimately lead to an increase in the volume of export.

Palestine.

41. The importance of Palestine as a producer and exporter of oranges is growing rapidly. The area under cultivation has more than doubled between the years 1924 and 1928, and the rate of planting is apparently increasing year by year. The area of new plantations and the total under cultivation for the past six years is shown below :—

TABLE XII.—*Orange Cultivation in Palestine.*

Year.	Area of New Plantations.	Total Area under Orange Cultivation.
	Acres.	Acres.
1923	—	5,400
1924	450	5,900
1925	1,130	7,000
1926	1,590	8,600
1927	1,590	10,200
1928	3,400	13,600

42. A steady and considerable increase in orange production may thus be looked for. According to the report of the Palestine Fruit Commission bearing commences frcm six to eight years after plantation, and it seems evident that hardly any of the 8,000 acres added since 1923 can yet be in bearing. Production is thus likely to increase fully 100 per cent. within a few years, and even then the limit of production of the present groves will not be reached. Moreover planting is still going on extensively.

43. The following table shows export of oranges in each calendar year from 1922 to 1927.

TABLE XIII.—*Exports of Oranges from Palestine.*

Year.	*Quantity. Thousand cwt.**
1922	863
1923	1,109
1924	1,310
1925	1,301
1926	1,315
1927	1,851

* Converted from boxes at 78 lb. per box.

44. The bulk of the exports are destined for the United Kingdom, but large quantities of fruit of lower quality are sent in bulk to Egypt. Recent returns show that direct shipment to continental markets (mainly Germany) is increasing. The export season starts late in November and continues to about April. In table, XIV which shows exports by months for the past two seasons, the increasing exports to the continent are clearly shown; the figures are exclusive of the exports of fruit in bulk to Egypt.

45. The Jaffa orange is of quite distinctive type and is well famed for its sweetness and flavour. The best fruits go to the United Kingdom and to Northern European markets, large and thick skinned fruits are popular in Constantinople, although this market is less important than formerly, and, as stated above, the inferior grades go to Egypt and other markets in the Eastern Mediterranean.

TABLE XIV.—*Shipments of Boxes of Oranges from Palestine.*

Destination.	Nov.–Dec.	Jan.	Feb.	Mar.	Apr.	Total.
1926–27.						
United Kingdom ..	537,400	484,500	322,900	490,500	68,900	1,904,200
Germany	13,600	29,300	8,100	15,300	—	66,300
Rumania	4,500	8,000	9,700	11,300	—	33,500
Czechoslovakia	9,200	—	—	—	—	9,200
Denmark..	—	—	700	—	—	700
Bulgaria	500	—	—	600	—	1,100
Other countries	—	—	—	9,700	—	9,700
Total	565,200	521,800	341,400	527,400	68,900	2,024,700
1927–28.						
United Kingdom ..	504,500	438,900	245,100	437,300	103,400	1,729,200
Germany	60,900	19,600	25,000	36,000	—	141,500
Rumania	3,700	17,400	22,600	7,000	1,100	51,800
Holland	13,900	8,300	7,000	3,400	—	32,600
Czechoslovakia ..	7,400	—	—	—	—	7,400
Denmark..	1,500	2,700	800	11,600	—	16,600
Bulgaria	—	1,700	600	400	—	2,700
France	3,000	2,900	1,800	1,200	—	8,900
Belgium	—	500	—	—	—	500
Other countries	2,700	1,900	400	—	—	5,000
Total	597,600	493,900	303,300	496,900	104,500	1,996,200

46. A considerable proportion of the fruit is liable to become wasty, particularly towards the end of the season, and as in so many other producing countries the pressure of competition is forcing the growers to take some measures to safeguard their markets for the future. A system of inspection was inaugurated last season with a view to raising the standard of fruit exported to the principal markets.

Union of South Africa.

47. The Union of South Africa is fast developing as an orange producer and very rapidly increasing supplies may be expected from this area. A special census of fruit trees was taken in 1927 and the results were published in the October Bulletin of Union Statistics. The following table shows the number of orange trees at different ages in each of the main provinces.

TABLE XV.—*Number of Orange Trees grown for commercial purposes in the Union of South Africa*, 1927.

Age.	Cape.	Natal.	Transvaal.	Total.
Under 3 years	351,025	21,903	575,981	948,909
3 to 4 years	122,953	38,627	600,335	761,915
5 to 7 years	148,726	40,783	472,160	661,669
8 years and over	245,092	32,809	400,134	678,035
Total (all ages)	867,796	134,122	2,048,610	3,050,528

48. These figures show that about 55 per cent. of the trees were below five years of age and consequently not yet yielding appreciable quantities of fruit. Only about 20 per cent. had reached the full bearing age. A greatly increased production is therefore to be expected.

49. Information was also collected regarding the number of orange trees growers were proposing to plant in the near future, showing that the total number of trees was likely to be increased between 20 and 25 per cent. in the next two or three years, as shown below :—

TABLE XVI.—*Proposed Plantings of Orange Trees in the Principal Orange-growing Areas of the Union.*

Cape	238,261
Natal	17,003
Transvaal	416,466
Total ..	671,730

50. Exports of oranges and naartjes (tangerines) from the Union of South Africa are almost exclusively to the United Kingdom, no less than 560,000 boxes of oranges out of a total of 563,000 being consigned thither in 1926, while in the case of naartjes the United Kingdom takes an even larger proportion. The following table gives the exports for the years 1924, 1925 and 1926, showing countries of consignment :—

TABLE XVII.—*Exports of Oranges and Naartjes.*

Exported to	Oranges.			Naartjes.		
	1924.	1925.	1926.	1924.	1925.	1926.
	Boxes.	Boxes.	Boxes.	Boxes.	Boxes.	Boxes.
United Kingdom ..	398,366	659,230	559,650	55,811	65,794	16,029
India	18	135	—	—	—	—
Ascension Is.	9	38	42	1	—	3
Mauritius	53	182	69	—	59	—
St. Helena	15	40	42	—	—	6
Kenya Colony	—	3	133	—	—	—
Germany	—	—	1,800	—	—	—
Holland	—	—	137	—	—	—
Belgian Congo	7	83	363	—	113	—
Portuguese East Africa ..	555	658	302	210	124	—
Madagascar	—	28	—	—	—	—
Total ..	399,023	660,397	562,538	56,022	66,090	16,038

51. The rapid development of the Union's export trade in oranges since the war is illustrated by the table given below, showing the shipments of oranges and naartjes to the United Kingdom from 1910 to 1927, the number of boxes having increased by over 680 per cent. since 1920. The figures include shipments from Rhodesia and Portuguese East Africa through Union ports.

TABLE XVIII.—*Shipments of Oranges and Naartjes from South Africa.*

Year.	Oranges.	Naartjes.
	Boxes.	Boxes.
1910	10,387	—
1911	14,573	12,403
1912	15,773	2,614
1913	29,384	7,825
1914	43,568	25,400
1919	45,439	5,361
1920	108,048	4,867
1921	217,746	22,236
1922	282,585	38,102
1923	356,087	41,103
1924	445,917	57,518
1925	676,368	67,500
1926	583,591	16,177
1927	845,276	57,918

52. The very striking increase in future production indicated by the foregoing tables suggests that the exportable surplus may easily be trebled or quadrupled within a relatively short time.

53. The Washington Navel and the Valencia Late are the chief varieties of oranges grown, together with naartjes (tangerines), and small quantities of other varieties. Most of the fruit is shipped co-operatively, and a rigid system of Government inspection is in force to maintain the high standard of quality, packing and grading for which the South African fruit is famed. Increasing competition may lead to a further raising of the standard for export, and the retention for domestic use of oranges of quality which is now permitted to be exported; but this would modify to only a slight extent the increasing surplus of fruit available for export, and would make still more imperative the question of discovering a suitable means of disposing of the large proportion of culled fruit.

Southern Rhodesia.

54. Exports of oranges from Southern Rhodesia have rapidly expanded since the first commercial consignment to the United Kingdom in 1916, during which year the total quantity exported to Europe was only 1,300 boxes, as compared with 45,000 boxes in 1923. During the latter year there were 172,000 orange trees, of which 99,000 were in bearing and 73,000 not in bearing. This number had increased in 1926–27 to 204,500, of which 158,500 were bearing and 46,000 not in bearing.

TABLE XIX.—*Exports of Oranges from Southern Rhodesia.*

Years.	*No. of Boxes.*
1916	1,336
1919	2,339
1920	7,675
1921	15,422
1922	22,663
1923	44,760
1927	118,069

55. There seems little doubt that production in Southern Rhodesia will develop further, as the number of trees in full bearing increases.

Exports are made mainly through Union ports and Beira, and the above figures are partly included in certain of the South African exports given earlier.

France.

56. Small quantities of oranges and mandarines are produced in France, the approximate result of the harvest in the various districts for 1927, according to the Bulletin de l'Office de Renseignements Agricoles, being as follows :—

TABLE XX.—*Approximate Production of Oranges and Mandarines, 1927.*

Department.	Oranges.	Mandarines.
	Cwt.	Cwt.
Alpes Maritimes	4,530	3,310
Corse	2,360	3,540
Hérault..	20	—
Pyrénées Orientales	40	—
Total	6,950	6,850

57. The production of oranges appears to be decreasing, however, the 1927 crop being only half that of 1925, and only one-fifth of that of 1913, the figures being :—

TABLE XXI.—*Production of Oranges and Mandarines in France.*

Year.	Oranges.	Mandarines.
	Cwt.	Cwt.
1913	36,600	3,600
1925	13,600	8,800
1926	7,700	6,800
1927	6,900	6,800

58. It is not possible to give the exports of oranges from France as the Trade Returns do not distinguish between that fruit and lemons. As regards mandarines, however, the necessary particulars are

available. Total exports of French produced mandarines and China oranges amounted to about 10,000 cwt. in 1926, as against 6,000 cwt. in 1925; but the quantities for 1927 are far below those of the two previous years, amounting to only 2,000 cwt. It is probable that these figures include re-exports of Algerian produce, as it will be noted that in 1926, the quantity exported is greater than the production. The details of exports for the past few years, as compared with 1913, are as given below, the chief countries to which the fruit is consigned being Germany, Belgium and Switzerland.

TABLE XXII.—*Exports of French produced Mandarines and China Oranges.*

	Cwt.
1913	500
1922	600
1923	900
1924	13,400
1925	6,200
1926	9,700
1927	2,100

59. There seems no prospect of development in the export of oranges and mandarines from France. France is already a large importer and the small domestic production is of little account and is tending to decline.

Portugal.

60. Exports of oranges from Portugal are shown by number only, and exports during the past few years as compared with 1913 are shown below, the principal countries of consignment being Spain and the United Kingdom :—

TABLE XXIII.—*Exports of Oranges from Portugal.*

	Thousand.
1913	2,078
1921	3,599
1922	6,119
1923	5,935
1924	2,858
1925	2,520
1926	268

61. At an average of about 300 to the cwt., exports would amount to only 1,000 cwt. in 1926, and in the peak year would represent only 20,000 cwt. There seems little prospect of Portugal developing a substantial export trade in oranges.

Cyprus.

62. Fair quantities of oranges are grown in Cyprus and cultivation is said to be increasing. Production in 1927 amounted to 28,000,000 as compared with 30,000,000 in 1926. There is a considerable export trade, nearly 21,000,000 fruits being exported in 1927. Up to the present, exports have been mainly to Egypt and Greece, but there are possibilities of wider markets being developed in future. The quality of the fruit is said to compare not unfavourably with the Jaffa product, which it resembles, and that exports to the United Kingdom have not yet begun on a commercial scale is stated to be due mainly to lack of adequate transport facilities.

63. Exports are shown in the official trade returns by number only. The exports for the years 1925 to 1927 are shown in the following table :—

TABLE XXIV.—*Exports of Oranges from Cyprus.*

Exported to.	1925.	1926.	1927.
	Thousand.	Thousand.	Thousand.
Egypt	11,561	10,620	13,714
Greece	4,925	3,581	7,006
Turkey	14	28	1
United Kingdom	267	25	17
Syria	234	7	14
Dodekanesia	4	6	—
Rumania	200	—	—
Sea	7	8	21
France	20	—	—
Castellerizo	—	—	2
Total	17,232	14,275	20,775

64. Assuming the fruit to be comparable in size to the Palestine product, exports in 1927 would represent a weight of over 90,000 cwt.

Algeria.

65. According to the report of the Department of Overseas Trade, the total output of oranges in 1925–26 in Algeria was 37,110 tons, while the mandarine crop amounted to 54,300 tons. The combined total of oranges and mandarines was thus as great as that of Palestine up to two years ago, but the increase in production in the latter country has put it definitely ahead.

66. The following table gives the areas under cultivation and the output in the various districts :—

TABLE XXV.—*Areas under Orange Cultivation and Output in Algeria in 1925–26.*

Department.	Oranges.		Mandarines.	
	Acres.	Thousand cwt.	Acres.	Thousand cwt.
Algiers	4,330	450	4,860	908
Oran	4,320	171	1,890	76
Constantine	2,340	120	1,710	102
Total	10,990	741	8,460	1,086

67. The area under citrus fruit is growing steadily and the production of oranges increased from about 570,000 to 740,000 cwt. between 1921–22 and 1925–26, while the yield of mandarines increased from 640,000 to 1,090,000 cwt. in the same period. Mandarines are the chief citrus fruit exported, but growers are reported to be considering the possibility of planting American orange trees to obtain a fruit suitable for export.

68. Exports of oranges and mandarines for 1926 and 1927 as compared with 1913 are shown below :—

TABLE XXVI.—*Exports of Oranges and Mandarines from Algeria.*

	1913.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.
Oranges	72*	153	93
Mandarines	133	469	246

* Includes lemons.

69. Practically the whole of these exports are destined for France, where they are favoured by tariff preference ; 152,000 cwt. of oranges and 460,000 cwt. of mandarines were consigned to France in 1926. There seems little probability at present of any appreciable quantities being shipped to other markets, but the increasing supplies sent to France limit the quantities that that country can absorb from other producers.

Syria.

70. According to the Italian National Export Institute the production of citrus fruits in Syria in 1926–27 amounted to about 448,000 cwt. and in 1927–28 to 344,000 cwt., but only about 70 per cent. of these are oranges, the remainder being lemons.

Exports of oranges for the years 1925, 1926 and 1927 are shown in the following table :—

TABLE XXVII.—*Exports of Oranges from Syria.*

Exported to	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.
Turkey	63	26	41
Egypt	77	26	31
United Kingdom	2	3	—
Other countries	38	21	—
Total	180	76	72

71. Egypt and Turkey take the bulk of the citrus fruit exported, but small quantities are sent to the United Kingdom.

Japan.

72. The production of oranges in Japan amounts usually to about 5,500,000 cwt., and Japan thus vies with Italy for third place among the world's producers of oranges. In 1925-26 production amounted to over 7,000,000 cwt. On the whole, production is tending to increase. In the following table are shown for 1914 and for each of the four years, 1922–23 to 1925–26, the number of orange trees and the total production of oranges in Japan :—

TABLE XXVIII.—*Japanese Orange Production.*

Number of trees.	1914.	1922–23.	1923–24.	1924–25.	1925–26.
	Thousand.	Thousand.	Thousand.	Thousand.	Thousand.
Mandarine	15,807	18,247	18,589	19,977	19,795
Navel orange	1,495	1,445	1,389	1,385	1,391
Bitter orange	3,675	3,465	3,281	3,319	3,402
Other orange*	3,362	2,277	2,179	2,204	2,274
Total	24,339	25,434	25,438	26,885	26,862
Production.	Thousand cwt.	Thousand cwt.	Thousand cwt.	Thousand cwt.	Thousand cwt.
Mandarines	2,900	4,212	3,955	3,941	5,387
Navel oranges	153	255	234	241	285
Bitter oranges	2,418†	678	936	1,109	1,244
Other oranges*	607	422	403	395	453
Total	6,078	5,567	5,528	5,686	7,369

* Prior to 1925–26, these were shown as "other citrus."

† This exceptionally large production has never since been approached; 1915 production amounted to only 827,000 cwt.

73. In comparison with the year 1914, there has been an appreciable increase in the number of mandarine trees, and in the annual crop of mandarines. The numbers of trees of other types of orange has shown no increase, and is tending to decline, but production appears to be fully maintained.

74. Although the bulk of the oranges produced in Japan are retained for home consumption, considerable quantities of oranges (mainly mandarines) are exported, totalling some 17,000 tons in 1926 and 1927. These are destined mainly for the Kwantung Province of China, but fair quantities are sent also to the United States and Canada. The 1927 total is not greatly in excess of that for 1913, but the trend of exports in recent years has been upward,

although there seems no reason to anticipate any great increase in exportation to western markets in the near future. The following table shows exports of mandarines during the six years, 1922 to 1927 indicating principal countries of consignment.

TABLE XXIX.—*Exports of Mandarines from Japan.*

Destination.	1922.	1923.*	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Kwantung Province ..	139	130	123	164	228	
China	27	33	21	37	55	(Not
Canada	47	64	39	44	25	avail-
U.S.A.	10	24	7	9	32	able.)
Asiatic Russia	12	4	3	2	2	
Other countries	2	3	—	1	—	
Total	237	258	193	257	342	334

* Does not include July and August for Yokohama, owing to loss of return at time of great earthquake.

75. In pre-war days Asiatic Russia was one of the principal markets, taking nearly as large a proportion of the exports as the Kwantung Province.

China.

76. Considerable quantities both of close-skinned and mandarine oranges are grown in Southern China, chiefly along the south-east coast, in the provinces of Chekiang, Fukien, and Kwangtung, but no production figures are available. The bulk of the production is consumed locally, and there are normally large shipments to Northern China, while there are also considerable exports, the total in 1926 being some 160,000 cwt., but China is also a large importer of oranges, receiving some 366,000 cwt. from abroad in the same year. Exports are mainly to Singapore, the Straits Settlements, Hong Kong, Siam, and French Indo-China. The following table shows the exports under countries for the six years, 1921–26.

TABLE XXX.—*Exports of Fresh Oranges from China.*

Exported to.	1921.	1922.	1923.	1924.	1925.	1926.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Singapore, Straits, etc. ..	123	64	44	89	65	83
Hong Kong	152	102	83	105	46	26
French Indo-China ..	17	17	13	27	20	28
Siam	62	46	23	43	26	19
Macao	3	3	1	2	4	2
Philippine Islands ..	1	1	1	1	1	3
Russia. Pacific Ports ..	1	—	—	—	—	—
Total exported abroad ..	359	233	165	267	162	161

77. The imports are mainly from Japan, but substantial quantities are received from the United States. The following table shows the imports under countries for the four years ended 1926 :—

TABLE XXXI.—*Imports of Fresh Oranges into China.*

Imported from.	1923.	1924.	1925.	1926.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Japan (including Formosa) ..	167	151	215	313
U.S.A. (including Hawaii)	9	13	15	31
Hong Kong	6	7	4	—
Korea	5	5	7	4
Russia (Pacific Ports)	—	—	9	18
Total	187	176	250	366

78. These two tables taken in conjunction suggest that, although exports fluctuate, they are on the whole tending to decline, whereas imports are tending to increase. China not only appears capable of absorbing the increasing exports from Japan, but is also providing an increasing outlet for the Californian surplus production.

Porto Rico.

79. Citrus fruits are grown to a very considerable extent in Porto Rico, but no figures of production are available. Oranges are of less importance than grape-fruit. Orange exports go almost entirely to the United States, although there have been some small consignments sent (via New York) to the United Kingdom. Shipments for the year ended 30th June, 1928, amounted to 546,000 boxes. Exports to the U.S.A. have been as follows in recent years :—

TABLE XXXII.—*Exports of Oranges from Porto Rico to the U.S.A.*

	Thousand cwt.
1925	303
1926	220
1927	259

80. The volume of imports from Porto Rico is, of course, small in relation to U.S.A. production, and their importance lies mainly in the fact that they precede the Florida crop by a few weeks.

Cuba.

81. The chief citrus fruit grown in Cuba is the grape-fruit, but the production of oranges for export is increasing, as is shown in the following table of the quantities exported for the three years ended 1926 compared with 1912 and 1913. Practically the whole are consigned to the United States.

TABLE XXXIII.—*Exports of Oranges from Cuba.*

Exported to.	1912.	1913.	1924.	1925.	1926.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
U.S.A.	64	122	187	165	222
Canada	1	1	1	5	2
Total	65	123	188	170	224

Jamaica.

82. Increasing quantities of oranges are being produced in Jamaica. In 1905–6 the area devoted to orange cultivation was 609 acres ; this had increased to 690 acres in 1915–16 and to 796 acres in 1927–28. Exports are mainly to the United Kingdom, but small

quantities are despatched to Canada. Exports in recent years are given in the following table :—

TABLE XXXIV.—*Exports of Oranges from Jamaica.*

Exported to.	1924.	1925.	1926.
	*000 cwt.	*000 cwt.	*000 cwt.
United Kingdom	55	67	83
Canada	1	5	2
Bermuda	—	1	1
Other countries	1	1	1
Total	57	74	87

* Converted at 78 lb. per box.

83. There are said to be possibilities of further expansion in Jamaica orange production, although the quantities exported are small in comparison with those exported from the more important supplying countries.

Australia.

84. In 1925–26, 33,668 acres were under orange trees in bearing in Australia, mainly in New South Wales, and the total yield for the year was 3,300,000 bushels. As at that date there was also a considerable area not in bearing, the yield should show a considerable increase within a few years.

85. The acreage under oranges during recent years and the total production in each year are shown in the following table :—

TABLE XXXV.—*Area and Production of Oranges in Australia.*

Year.	Bearing.	Non-bearing.	Total.	Production.
	Acres.	Acres.	Acres.	000 bushels.
1919–20	29,344	11,372	40,716	2,263
1920–21	30,509	10,761	41,270	2,583
1921–22	31,097	11,066	42,163	2,864
1922–23	29,948	12,733	42,681	2,899
1923–24	30,580	14,181	44,761	2,821
1924–25	32,864	14,438	47,302	3,064
1925–26	33,668	12,816	46,484	3,326
1927–28	—	—	47,000	3,130

86. Over 60 per cent. of the orange area is in New South Wales, the remainder being divided more or less equally among Victoria, Queensland, South Australia and Western Australia.

87. Production, it will be seen, is increasing steadily, and while at present supplies are not much more than sufficient for domestic requirements, exports are increasing. Exports of citrus fruits (oranges are not separately distinguished) rose from about 41,000 cwt. in 1923–24 to 57,000 cwt. in 1924–25, and 114,000 cwt. in 1925–26, but fell to 59,000 cwt. in 1926–27. The bulk go to New Zealand, with smaller quantities to the United Kingdom and elsewhere.

88. The consumption of oranges per head of the population is as great in Australia as in almost any other country in the world, and unless domestic consumption increases still further, or production is curtailed, an increasing surplus for export appears probable, although the introduction of juice extractors and orange drink stalls has recently resulted in a great increase in the demand.

Brazil.

89. Brazil is already a very large producer of oranges, and appears destined to become one of the leading sources of supply of oranges to Europe during the summer and autumn months. No official records or estimates of production are available, but the Bank of London and South America, in its "Monthly Review," has given an estimate of annual production in the leading States as follows :—Sao Paulo, 400 million fruit ; Minas Geraes, 220 million ; Rio de Janeiro, 200 million ; and Rio grande do Sul, 170 million ; a total of about 1,000 million oranges annually, or about 3½ million cwt. Only in Sao Paulo and Rio de Janeiro, however, is there any production on a commercial scale. The principal varieties grown in these States are the Navel and Pera varieties, with some production also of Valencias and mandarines. The State of Bahia, further north, also produces Navel oranges (the famous "Washington Navel" was first introduced into California from Bahia).

90. Table XXXVI below shows exports of oranges from Brazil in 1913, 1918 and during the seven years ended 1927. Official returns give exports by number only.

TABLE XXXVI.—*Exports of Oranges from Brazil.*

Year.	*Thousand Oranges.*
1913	395
1918	14,189
1921	17,457
1922	35,588
1923	66,136
1924	73,068
1925	81,271
1926	42,086
1927	64,371

In the peak year, 1925, over 80 million fruits, equivalent to fully 270,000 cwt., or 400,000 standard boxes, were exported, but average exports are only about 5 or 6 per cent. of total production and the bulk of the fruit is consumed in Brazil or wasted. Most of the exports go to neighbouring countries in South America, Buenos Aires and Montevideo being the chief markets, but in 1927 experiments were made with commercial shipments to Europe, and in 1928 some 200,000 boxes were shipped to Europe, the greater proportion going to the United Kingdom.

91. There are difficulties in the way of a rapid expansion of the orange export trade to Europe. There is relatively little cultivation, a large proportion of the trees being in a wild or semi-wild condition. Generally, however, the fruit is clean and of excellent quality. Transport facilities are very poor—oranges from Limeira, the principal producing area in Sao Paulo, take 2½ days to reach Santos, and no refrigerated cars are provided. But these obstacles are being overcome. It is estimated that already, in the two states of Sao Paulo and Rio de Janeiro, fully 1,000,000 boxes are suitable for export to European markets. Transport facilities are likely to be improved ; increasing attention is being given to methods of handling, packing and grading ; and better shipping facilities are expected in future years. Moreover, orange plantations are rapidly extending, and the new plantations are intended primarily for the European export trade. This very rapid extension of the orange area suggests that within the next decade the exportable surplus, suitable for European markets, may considerably exceed one million boxes.

92. The season of shipment runs from about May to September inclusive, and thus almost coincides with the South African shipping season, and it is evident that supplies of Brazilian oranges are likely to rival in quantity, and possibly in grading, the South African fruit, with which they already compare favourably in general quality.

Argentina.

93. There are indications that the Argentine Republic may become an exporter of substantial quantities of oranges in the future, as consignments to foreign countries are increasing rapidly, and, in fact, increased more than threefold between the years 1923 and 1927. These exports are mainly despatched to neighbouring South American countries, principally Uruguay, but shipments to the United Kingdom have been made in recent years, some 300 cwt. being sent in 1924, and 5,200 cwt. in 1926.

94. The following table shows the development of the export trade between 1923 and 1927, indicating the principal countries of consignment.

TABLE XXXVII.—*Exports of Oranges and Mandarines from Argentina.*

Exported to.	1923.	1924.	1925.	1926.	1927.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Uruguay	5,700	14,400	21,200	30,600	(Not available.)
United Kingdom ..	—	300	1,000	5,200	
Chile	—	—	400	500	
United States	100	500	200	200	
Italy	—	100	—	—	
Germany	—	100	—	300	
English Possessions ..	—	—	—	100	
Total	5,800	15,400	22,800	36,900	27,500

95. The Argentine Republic imports large quantities of oranges, some $735,000 worth entering the country in 1927. These come

chiefly from Paraguay and Uruguay, but consignments are also received from Brazil and Spain. Imports are not shown by quantities and the only basis of comparison with exports is by value ; exports of oranges from the Argentine were valued at $74,550 in 1927, as compared with imports to the value of $734,612.

96. In spite of the excess of imports over exports, however, there are prospects of increasing shipments of Argentine fruit to Europe. The railway companies are fostering the development of orange growing for export purposes, and experts have been sent to California and South Africa to ascertain the best export varieties and methods of cultivation, and to the United States and Europe to study market conditions. Seedless oranges from the islands of the *Párana* delta have been sent to the United Kingdom and further shipments are likely. In Entre Rios, where there are already some 100,000 orange trees, plantations are extending, improved methods of handling are being introduced, and a large export trade is expected in a year or two, while it is estimated that from 20 to 25 per cent. of the mandarine production of this area (the number of trees is about 400,000) is already suitable for export, and improved cultural methods would substantially increase this proportion.

Ecuador.

97. Exports of oranges are mainly to Chile and Peru, the details for 1925 being shown in the following table :—

TABLE XXXVIII.—*Exports of Oranges from Ecuador*, 1925.

	Cwt.
Chile	52,100
Panama	100
Peru	31,200
Total	83,400

98. Total exports for a series of years compared with three pre-war years are as follows :—

TABLE XXXIX.—*Exports of Oranges from Ecuador.*

	Cwt.
1911	39,100
1912	22,900
1913	41,500
1921	33,100
1922	35,700
1923	62,000
1924	26,700
1925	83,400

Exports appear to be increasing, but no movement to ship overseas has yet been made and it is probable that the character and quality of the fruit are such as to make such exports impracticable, at any rate for the present.

Paraguay.

99. The orange growers in Paraguay are mostly under the control of the Banco Agricola, which is stated to have already effected substantial improvements in the methods of grading and packing. Exports, which are shown only by number, are considerable, and for the six years ending 1927 have been as follows :—

TABLE XL.—*Exports of Oranges and Mandarines from Paraguay.*

	Million.
1922	131
1923	222
1924	193
1925	240
1926	216
1927	140

100. Oranges in Paraguay are mostly wild, and there are few regular plantations. The fruit is of Valencia type of fine flavour and medium size. Exports are almost entirely to Argentina, but a quantity equal to that exported is stated to be allowed to rot. There are big possibilities of developing an export trade to Europe, in spite of prevalence of disease resulting from lack of care of the trees. It is estimated that once cultivation commenced, within a short period 150,000 boxes could be exported, the season running from May to July. Considerable improvements in methods of handling, packing and grading would, however, be necessary. Recent restrictions placed by the Argentine Government upon oranges imported from Paraguay have increased the probability of the Paraguayans seeking

an outlet in Europe for part of their production in future. Considerable quantities of mandarines are also grown, similar in shape to the South African naartje, but the general quality of this fruit is less satisfactory than that of Argentina and Uruguay.

Uruguay.

101. In the provinces of Salto (facing, across the River Uruguay, the province of Entre Rios in Argentina) and of Rivera, considerable quantities of oranges are produced. Hitherto considerable quantities of the fruit have found a market in Montevideo, with relatively small quantities exported to Buenos Aires, but the latter market (as in the case of Paraguayan fruit) is now restricted by import regulations, and it is reported that shippers are anxious to develop markets overseas. There are in the province of Salto some 300,000 mandarine and 100,000 orange trees, and plantations of the latter are extending rapidly. About 40 per cent. of the orange production is stated to be at present suitable for export to European markets, and exports next year are expected to reach 40,000 to 50,000 packages of mandarines and 75,000 to 100,000 boxes of oranges. As regards Rivera, annual production is estimated at about 6,000,000 fruits, about three-fifths of which are suitable for export. Plantations are expanding rapidly. Large exports are possible within a few years, as methods of handling, packing and grading improve, and the new plantations, developed with a view to export possibilities, come into bearing.

Other Producing Countries.

102. There are a number of other countries producing greater or smaller quantities of oranges, and most of them have some export trade. Among these may be mentioned—

Greece, which exports about 50,000 cwt. of all citrus fruits (including lemons), mainly to Bulgaria, Rumania and Russia ;

Turkey, which produces oranges mainly for local consumption, and exports fair quantities to the Black Sea ports of Russia and elsewhere ;

Malta, producing oranges and mandarines and exporting a few hundred cwts. to the United Kingdom each year ;

India, where considerable quantities of oranges are grown for local consumption, chiefly the " Nagpur " variety, a large thick-skinned juicy orange grown in the hilly districts of central India, and the " loose jacket," of tangerine type, grown in the west. There are no exports ;

Trinidad and other British West Indies, which grow small quantities and export mainly to other West Indian Islands. Trinidad in 1927 exported over 2½ million oranges;

Costa Rica, whose small exports (about 6,000 cwt. in 1925) go mainly to the United States;

Mexico, which in 1926 exported about 4,000 cwt. to the U.S.A.

Colombia, Peru and Chile, which all grow oranges, mainly for local consumption. No recent statistics of exports are available, but Chile and Peru import substantial quantities of oranges from Ecuador, and their own export trade in the fruit is not considerable.

Cook Islands, in the Pacific, from which New Zealand obtained 52,000 cwt. of oranges in 1925; 91,000 cwt. of oranges and 200 cwt. of mandarines and grape-fruit in 1926; and 65,000 cwt. of oranges and 270 cwt. of mandarines and grape-fruit in 1927;

New Zealand, which produces about 2,000 cwt. of oranges in North Island.

103. None of these are important in world trade, their exports being restricted to a limited number of markets. In so far, however, as they supply domestic or foreign markets which might otherwise call upon the surplus from the larger exporting countries, they cannot be overlooked.

IMPORTS.

United Kingdom.

104. The world's largest importer of oranges is the United Kingdom, which imported nearly 8,000,000 cwt. both in 1926 and in 1927. Since the war the quantity has been steadily increasing, and the figure for 1927 represents an 80 per cent. increase on that for 1920. Imports are now considerably in advance of those for pre-war years. During the last ten complete years before the war there was little variation in the quantity annually imported, this being invariably between 5,000,000 and 6,000,000 cwt., while during each of the five years ending 1927, the quantity has been between 7,500,000 and 8,000,000 cwt. The annual average imports for the five years ending 1927 were 7·8 million cwt., as compared with 5·7 million cwt. for the five years ending 1913, an advance of 37 per cent. In considering these figures notice must be taken of the re-exports, but the quantity of these has not varied much

between recent and pre-war years. The annual average quantity re-exported in the five years ending 1913 was 230,000 cwt., as compared with 223,000 cwt. in the five years ending 1927. The following table shows the total imports and re-exports for the years 1920 to 1927 as compared with the last five pre-war years :—

TABLE XLI.—*United Kingdom Imports and Re-Exports of Oranges.*

Year.	Imports.	Re-exports.
	1,000 cwt.	1,000 cwt.
1909	6,202	224
1910	5,470	255
1911	5,284	189
1912	5,562	239
1913	5,793	253
1920	4,402	30
1921	5,858	86
1922	6,983	103
1923	7,626	164
1924	7,520	280
1925	7,729	216
1926	7,973	201
1927	7,898	255

105. Spain is the principal country from which the United Kingdom imports of oranges are obtained, and 67 per cent. of the total were from this source in the year 1927. Of the remaining countries, Palestine sent 17 per cent., the Union of South Africa 6 per cent., United States 6 per cent., Egypt 1 per cent., Italy 1 per cent., British West Indies 1 per cent., and various other countries very small quantities.

106. Imports from Spain have shown a decline during the past few years, but this is mainly due to the adverse weather conditions experienced in that country, December frosts occurring both in 1925 and 1926. Nevertheless, the annual average imports from Spain for the five years ending 1927 is 6,000,000 cwt. as compared with 5,000,000 cwt. for the five years ended 1913, an increase of 20 per cent.

107. The following table shows the imports of oranges into the United Kingdom since the year 1920 compared with five pre-war years, and details the principal countries of consignment :—

TABLE XLII.—*Imports of Oranges into the United Kingdom.*

(In thousands of cwt.)

Country whence consigned.	1909.	1910.	1911.	1912.	1913.	1920.	1921.	1922.	1923.	1924.	1925.	1926.	1927.
Spain	5,493	4,818	4,522	4,955	5,022	3,920	5,210	6,125	6,474	6,146	6,010	6,096	5,291
Turkey (Asiatic) ..	365	359	409	372	520	124	—	—	—	—	—	—	—
Palestine	—	—	—	—	—	—	245	472	690	805	975	1,004	1,359
Syria	—	—	—	—	—	—	—	1	7	7	23	55	3
British South Africa	—	—	—	6	12	79	137	172	210	273	426	377	524
United States ..	44	33	43	44	24	8	29	4	29	80	28	156	431
Egypt	7	5	2	4	3	25	33	24	24	30	82	53	53
Italy	130	105	188	83	115	162	103	67	63	56	58	54	92
British West Indies	124	129	92	85	74	57	70	64	73	60	70	86	61
Portugal	14	3	8	4	3	4	6	13	13	4	5	3	3
Canary Isles ..	—	—	—	—	—	—	—	3	3	12	8	11	3
Argentina	—	—	—	—	—	—	—	—	—	1	3	14	12
Australia	—	—	—	—	—	—	—	24	23	12	21	1	2
Germany	7	5	5	5	9	—	7	2	2	9	4	23	18
France	1	2	—	1	—	9	4	2	3	3	5	8	1
Other countries ..	17	11	15	3	11	14	14	10	12	22	11	32	45
Total ..	6,202	5,470	5,284	5,562	5,793	4,402	5,858	6,983	7,626	7,520	7,729	7,973	7,898

Note :—Countries of consignment are not necessarily countries of production. For example, the bulk of the oranges shown as imported from Egypt consists of Palestine fruit re-exported, and imports from Germany similarly consist of fruit previously imported into that country.

108. Supplies from Palestine have rapidly developed during recent years and have increased fivefold since 1921. Steadily increasing supplies have also been obtained from the British South Africa, an import of 79,000 cwt. in 1920 having expanded to 524,000 cwt. in 1927, while imports from the United States have increased from 28,000 cwt. in 1925 to 431,000 cwt. in 1927, and it is evident that the United States has now gained a position in the British market which she will make every effort to consolidate. The quantities received from Italy, however, are only about half those of pre-war years, the annual average for the five years ending 1927 being 65,000 cwt., as compared with 124,000 cwt. for the five years ending 1913. The West Indies have declined also as a source of supply, the imports for the past five years averaging 70,000 cwt. as compared with an average of 100,000 cwt. for the last five complete pre-war years.

109. Spanish oranges dominate the United Kingdom market from November to June and fairly substantial quantities are usually received in July, but arrivals from August to October are small.

110. The main season for the imports from Jaffa is from December to April, while the chief months for the arrival of South African oranges are from July to November. It will thus be readily seen that South African oranges do not compete, except at the beginning and end of their season, with Spain and Palestine, the two main sources of supply.

111. United States oranges are imported throughout the year, but the heaviest arrivals are from May to November, the period of the year when Spanish and Palestine shipments are either diminishing or are negligible, and South African shipments have to meet increasing competition from this source of supply, as well as the probable increased imports from South America. Of the total imports of oranges in August, 1927, half were from the United States, and of the September total over 40 per cent. were from the same country.

112. Oranges are imported from Italy mainly from January to March, from the British West Indies mainly from October to December, from Australia from June to December, and from Brazil from May to December.

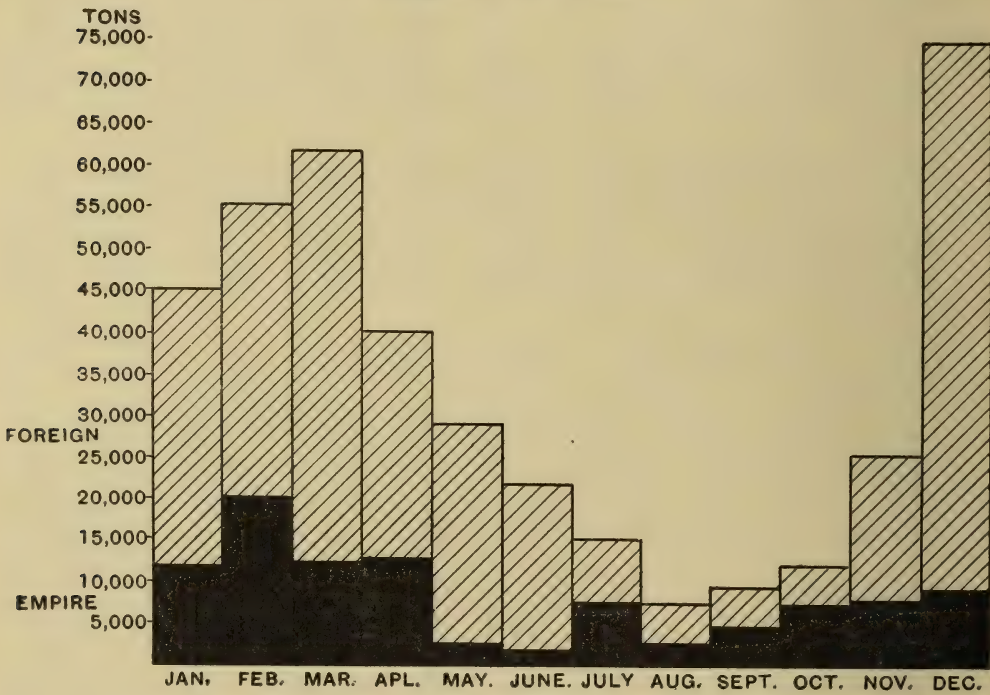
113. The following table shows the imports of oranges into the United Kingdom from the principal producing countries during each month in the years 1925, 1926 and 1927 :—

TABLE XLIII.—*Imports of Oranges into the United Kingdom each month,* 1925–27.
(000 cwt.)

	Spain.	Pales-tine.	South Africa.	U.S.A.	Italy.	South America.	British West Indies.	Other Coun-tries.
January—								
1925	1,176	153	—	7	24	—	—	20
1926	972	176	—	1	16	—	—	49
1927	641	229	—	16	13	—	—	17
February—								
1925	887	205	—	2	12	—	—	11
1926	644	164	7	3	16	—	—	29
1927	644	407	—	10	35	—	—	8
March—								
1925	1,018	277	—	3	9	1	—	25
1926	1,150	234	—	11	5	8	—	21
1927	937	242	—	10	25	—	—	18
April—								
1925	749	224	—	2	2	—	—	19
1926	633	234	—	8	4	—	—	5
1927	539	250	—	17	4	—	—	4
May—								
1925	660	12	—	3	1	—	—	6
1926	567	2	1	10	3	—	—	13
1927	491	50	1	27	3	—	—	3
June—								
1925	276	14	2	2	4	—	—	2
1926	646	1	18	15	5	—	—	13
1927	337	—	30	48	5	2	—	6
July—								
1925	61	—	70	2	2	—	—	—
1926	215	6	129	26	1	1	—	13
1927	95	—	137	58	2	5	—	7
August—								
1925	3	—	124	3	—	1	1	1
1926	15	—	120	19	2	4	—	4
1927	8	—	54	71	—	8	—	3
September—								
1925	1	—	84	1	—	1	—	12
1926	—	—	66	22	1	1	—	1
1927	1	—	88	73	—	8	—	2
October—								
1925	—	—	81	2	—	—	28	11
1926	2	—	34	22	—	—	31	8
1927	1	1	128	83	—	4	7	4
November ..								
1925	148	5	49	1	1	—	27	14
1926	153	4	2	16	—	—	37	10
1927	313	45	65	24	3	1	34	18
December—								
1925	1,032	85	16	—	3	—	14	37
1926	1,099	183	—	3	1	—	18	18
1927	1,284	136	21	1	2	3	20	19
Total—1925 ..	6,011	975	426	28	58	3	70	158
1926 ..	6,096	1,004	377	156	54	14	86	184
1927 ..	5,291	1,360	524	438	92	31	61	109

114. The months when the imports are heaviest are naturally those in which the arrivals from Spain are heaviest, namely, November to June or July, while comparatively small quantities only are received in August, September, October and early November. Of the total imports for the twelve months in each year, the quantity received in the three months August, September and October, was only 7 per cent. in 1927, 4 per cent. in 1926, and 5 per cent. in 1925. This is the period when supplies are available from South Africa, United States, Brazil and Argentina, and increasing quantities may be expected from these sources in future. Diagram I shows monthly imports from Empire and foreign sources in 1927.

DIAGRAM I.—*Monthly Imports of Oranges into the United Kingdom in* 1927.



Germany.

115. Germany is the second largest importer of oranges in the world, receiving about 4,000,000 cwt. in each of the three years ended 1927. This represents an advance of nearly 40 per cent. on the 1913 total.

The following table shows the imports of oranges and mandarines from 1920 to 1927 as compared with 1913, and indicates the principal countries of origin :—

TABLE XLIV.—*Imports of Oranges and Mandarines into Germany.*

Imported from.	000 cwt.								
	1913.	1920.	1921.	1922.	1923.	1924.	1925.	1926.	1927.
Spain	2,488	72	330	222	98	1,906	2,993	2,737	2,728
Italy	337	292	828	152	169	1,150	1,084	957	1,315
United States	1	—	—	—	—	—	1	20	11
British South Africa	1	—	—	—	—	—	8	3	13
Algeria	—	—	—	—	—	—	1	3	(*a*)
Palestine	—	—	—	—	—	—	1	3	37
Brazil	—	—	—	—	—	—	—	2	13
France	7	1	—	—	—	11	3	10	12
Other countries	25	5	1	1	1	15	17	8	9
Total	2,859	370	1,159	375	268	3,082	4,108	3,743	4,138

(*a*) Included in other countries.

116. The above table shows that the bulk of the imports come from Spain, although large quantities are from Italy, but supplies from the other producing countries are comparatively small. It is interesting to note the decline in relative importance, as compared with 1913, of Spain as a source of supply, while Italy had advanced. In 1913 Spain supplied 87 per cent. of the total quantity imported and Italy 12 per cent., while in 1927 Spain supplied 66 per cent. and Italy 32 per cent.

117. As regards the principal months in which the imports are effected, the bulk are obtained from December to May, the main countries of origin during this period being Spain and Italy. During the remaining six months of the year—from June to November—comparatively small quantities are imported, but Spain and Italy are still shown as the main sources of supply, although there are small amounts from the United States, British South Africa, and in 1927 from Brazil. Of this slack period the months of August, September, and October, when very small quantities only are imported, are the quietest. The total imports of oranges and mandarines into Germany and the quantities from Spain, Italy and other countries for each month of the years 1925, 1926 and 1927, are given below :—

TABLE XLV.—*Imports of Oranges and Mandarines into Germany each month*, 1925–27.

Month.		Spain.	Italy.	Other Countries.	Total.
		000 cwt.	000 cwt.	000 cwt.	000 cwt.
January—	1925 ..	443	210	1	654
	1926 ..	455	134	2	591
	1927 ..	473	157	5	635
February—	1925 ..	662	307	8	977
	1926 ..	567	153	2	722
	1927 ..	483	345	14	842
March—	1925 ..	638	217	3	858
	1926 ..	573	231	19	823
	1927 ..	447	341	13	801
April—	1925 ..	539	35	4	578
	1926 ..	323	185	5	513
	1927 ..	396	225	6	627
May—	1925 ..	345	116	1	462
	1926 ..	246	128	2	376
	1927 ..	242	127	3	372
June—	1925 ..	40	32	2	74
	1926 ..	64	27	2	93
	1927 ..	52	23	5	80
July—	1925 ..	15	13	—	28
	1926 ..	19	26	1	46
	1927 ..	12	33	6	51
August—	1925 ..	5	11	1	17
	1926 ..	3	2	1	6
	1927 ..	5	1	6	12
September—	1925 ..	3	—	1	4
	1926 ..	—	—	1	1
	1927 ..	—	—	6	6
October—	1925 ..	—	—	2	2
	1926 ..	1	1	3	5
	1927 ..	4	1	6	11
November—	1925 ..	2	12	4	18
	1926 ..	12	5	2	19
	1927 ..	34	10	11	55
December—	1925 ..	301	132	3	436
	1926 ..	474	65	9	548
	1927 ..	580	52	14	646
Total—1925	.. ..	2,993	1,085	30	4,108
1926	.. ..	2,737	957	49	3,743
1927	.. ..	2,728	1,315	95	4,138

France.

118. France is an important market for oranges, but it is not possible to determine accurately the quantity imported, as oranges are grouped with lemons in the Trade Returns, although separate statistics are given for mandarines and China oranges. Practically all the imports from Spain are oranges, but a substantial part of the fruit imports from Italy are lemons.

119. Spain is the principal source of supply, and over 80 per cent. of the total oranges and lemons came from that country in 1927. Large quantities were from Italy, while substantial amounts came from Algeria and small quantities from Palestine, Syria and the United States.

120. The following table shows the imports of lemons and oranges for the six years ended 1927 compared with 1913, distinguishing principal countries whence consigned.

TABLE XLVI.—*Imports of Lemons, Oranges and their varieties into France.*

Imported from.	1913.	1922.	1923.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Spain	2,623	415	1,429	2,073	2,296	2,175	1,737
Italy	68	1,309	925	547	457	390	296
Algeria	61	122	88	102	60	169	85
Palestine	—	—	1	1	3	1	
Syria	—	—	—	—	2	—	
Turkey	4	2	—	—	—	—	
United States	—	—	—	2	3	3	
Tunis	4	—	—	—	1	3	
Great Britain	7	2	2	1	2	2	21
Belgium	1	—	1	1	1	2	
Switzerland	—	4	3	—	—	—	
Denmark	—	2	—	—	—	—	
Portugal	—	4	—	—	—	—	
Other countries.. ..	1	2	2	5	1	2	
Total	2,769	1,862	2,451	2,732	2,826	2,747	2,139

121. Considerable quantities of oranges and lemons are re-exported from France, the principal countries of consignment being Switzerland, Germany and Belgium. The following table shows the re-exports from 1922 to 1927 as compared with 1913.

TABLE XLVII.—*Re-exports of Lemons, Oranges and their varieties from France.*

Re-exported to.	1913.	1922.	1923.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Switzerland	163	70	38	193	290	407	—
Belgium	130	70	81	83	153	129	—
Germany	240	—	—	64	117	150	—
Other countries.. ..	7	15	21	62	13	3	—
Total	540	155	140	402	573	689	1

122. The principal importing months are December to June, when the Spanish shipments are heaviest, and comparatively small quantities are obtained from July to November. The following table shows the imports of lemons and oranges for each month of the year 1926 and 1927, indicating the principal countries of consignment :—

TABLE XLVIII.—*Imports of Lemons, Oranges and their varieties into France,* 1926 *and* 1927.

(Thousands of cwt.)

Imported from.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
					1926.							
Spain	243	333	430	333	321	136	24	14	12	4	44	282
Italy	30	26	21	22	59	33	36	38	35	29	14	47
Algeria	26	20	29	32	28	4	—	—	—	—	9	20
Other countries ..	2	2	3	2	1	—	—	—	—	1	1	1
Total	301	381	483	389	409	173	60	52	47	34	68	350
					1927.							
Spain	200	387	266	329	174	35	7	6	5	9	76	243
Italy	35	42	21	40	7	35	23	14	14	13	28	24
Algeria	17	26	13	10	—	2	—	—	—	—	4	12
Other countries ..	2	2	2	3	2	2	—	—	1	1	2	2
Total	254	457	302	382	183	74	30	20	20	23	110	281

The relatively heavy imports during the months July to October are, of course, due to the inclusion of lemons, and the figures suggest that the quantity of oranges imported from Italy is very small, as was indeed indicated by Italian export figures.

123. Imports of mandarines and China oranges are mainly from Spain and Algeria. The following table gives the imports for the years 1922 to 1927, compared with 1913, and shows the principal countries of origin.

TABLE XLIX.—*Imports of Mandarines and China Oranges into France.*

Imported from.	1913.	1922.	1923.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Spain	115	98	195	379	334	379	243
Algeria	114	165	155	365	174	511	188
Italy	5	71	46	6	7	3	7
Other countries ..	—	1	1	—	—	6	
Total	234	335	397	750	515	899	438

124. Re-exports are mainly to Switzerland, but fair quantities are consigned to Germany, as shown in the following table for the years 1922 to 1927, compared with 1913.

TABLE L.—*Re-exports of Mandarines and China Oranges from France.*

Re-exported to.	1913.	1922.	1923.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Switzerland	21	15	14	54	54	126	—
Germany	18	—	—	4	16	66	—
Belgium	5	6	3	2	1	1	—
Other countries	1	2	2	1	1	3	—
Total	45	23	19	61	72	196	nil

125. The main importing months are December to April, as indicated in the following table of the monthly imports of mandarines and China oranges in 1926, showing principal countries whence consigned :—

TABLE LI.—*Imports of Mandarines and China Oranges into France in the year* 1926.
(000 cwt.)

Imported from.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Spain	104	78	16	1	2	—	—	—	—	—	11	165
Algeria	116	150	130	67	11	2	—	—	—	—	5	28
Other countries ..	7	1	1	—	—	—	—	—	—	—	—	—
Total	227	229	147	68	13	2	—	—	—	—	16	193

Belgium.

126. Oranges are not separately distinguished in the Belgian trade returns, being grouped with lemons. Increasing quantities of these two fruits are being imported, the yearly average for the three years ending 1927 being 578,000 cwt., as compared with an average of 455,000 cwt. for the two years ended 1921, and 504,000 cwt. for the three years ended 1913. The bulk of the supplies are from Spain, but substantial quantities are received from Italy, although it seems probable that these are mainly lemons. The quantities received from various countries during 1924 to 1927 compared with 1913 are shown in the following table:—

TABLE LII.—*Imports of Oranges and Lemons into Belgium.*

Imported from.	1913.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Spain	442	631	372	548	383
Italy	33	53	111	66	97
France	31	11	33	53	39
Great Britain	7	2	9	3	12
Other countries ..	7	2	6	1	
Total	520	699	531	671	531

127. The main months in which the fruit is imported are from November to May, comparatively small quantities only being recieved from June to October, and these, coming mainly from Italy, are probably mostly lemons. The following table shows the monthly imports by countries for 1926 and 1927.

TABLE LIII.—*Imports of Lemons, Oranges and the like into Belgium.* (000 cwt.)

Imported from.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
					1927.							
Spain	40	64	69	40	25	4	—	—	—	1	37	102
Italy	21	18	13	8	8	6	5	4	4	3	4	5
France	7	9	5	3	1	—	—	—	—	—	5	8
Other countries ..	4	1	1	1	—	—	—	1	1	1	2	—
Total	72	92	88	52	34	10	5	5	5	5	48	115
					1926.							
Spain	120	87	105	61	47	4	3	—	—	—	16	105
Italy	5	5	8	8	6	5	4	4	4	5	4	6
France	11	13	12	6	2	—	—	—	—	1	2	7
Other countries ..	1	—	—	1	—	1	—	—	1	—	—	—
Total	137	105	125	76	55	10	7	4	5	6	22	118

Poland.

128. Considerable quantities of oranges are imported each year into Poland, the principal source of supply being Italy. The imports of oranges for the six years ending 1927, and the chief countries of consignment are shown in the following table :—

TABLE LIV.—*Imports of Oranges and Mandarines into Poland.*

Imported from.	1922.	1923.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Italy	Particulars not available		228	252	112	134
Spain			151	98	4	4
Germany			48	73	1	8
Other countries			15	21	6	
Total	175	154	442	444	123	146

129. A very heavy reduction in imports was recorded in 1926 and figures for 1927 were also low. This is due to the fact that oranges are now classed as a "luxury" import, and can only be imported under restricted licence. The chief months in which the fruit is imported are from December to June, and only very small consignments are received from July to October. The monthly imports for 1927 and the principal countries of consignment are given below :—

TABLE LV.—*Imports of Oranges and Mandarines into Poland in 1927.*

Month.	Imports from.			
	Italy.	Spain.	Other Countries.	Total.
	Cwt.	Cwt.	Cwt.	Cwt.
January	45,300	500	2,500	48,300
February	8,500	500	—	9,000
March..	21,100	1,000	1,300	23,400
April	24,000	1,200	1,200	26,400
May	15,500	700	600	16,800
June	7,800	100	400	8,300
July	200	—	—	200
August	500	—	—	500
September	—	—	—	—
October	—	—	—	—
November	700	—	100	800
December	10,000	500	1,800	12,300
Total ..	133,600	4,500	7,900	146,000

Austria.

130. Rapidly increasing imports of oranges have been recorded into Austria during its post-war economic recovery, as only 1,730 cwt. were imported in 1921 as against 252,000 cwt. three years later. The figure for 1926, however, was the same as that for 1925 at 314,000 cwt., and 1927 showed a slight reduction. Practically the whole of the imports are from Italy, and the quantity from Spain is very small by comparison.

131. The following table shows the imports of oranges (including peels) by countries during recent years.

TABLE LVI.—*Imports of Oranges and Peels into Austria.*

Imported from.	1921.	1922.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Italy	Particulars not available.			304	292	268
Spain				4	12	31
France				2	5	6
Trieste				3	2	—
Other countries				1	3	2
Total	2	68	252	314	314	307

132. The imports are mainly effected in the first and second quarters of the year, though fair quantities are received in the fourth (probably chiefly in December), while the amount received in the third quarter is practically negligible. The following table shows the imports by quarters for the year 1926 and for 1927.

TABLE LVII.—*Imports of Oranges and Peels into Austria.*

Imported from.	1926.			
	1st quarter.	2nd quarter.	3rd quarter.	4th quarter.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Italy	146	134	1	12
Spain	2	4	—	5
France	—	1	—	4
Trieste	1	1	—	1
Other countries	1	1	—	—
Total	150	141	1	22

TABLE LVII.—*Imports of Oranges and Peels into Austria—cont.*

Imported from.	1927.			
	1st quarter.	2nd quarter.	3rd quarter.	4th quarter.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Italy	143	110	3	10
Spain	13	5	—	13
France	4	—	—	2
Other countries	2	1	—	1
Total	162	116	3	26

Switzerland.

133. Substantial quantities of oranges are annually imported into Switzerland and the amount received has been increasing in recent years. Spain and Italy supply practically the whole, and very small quantities only are received from the other producing countries. Small consignments were received from Cuba and Brazil in 1926. The imports for home consumption for the years 1923 to 1927 and the quantities received from the various countries are shown below :—

TABLE LVIII.—*Imports of Oranges and Mandarines into Switzerland.*

Imported from.	1923.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Spain	43	134	173	207	184
Italy	194	118	83	94	104
Algeria	—	4	4	4	3
Other countries ..	—	—	—	—	1
Total	237	256	260	305	292

134. The principal months of importation are from December to May and particularly small quantities are received from August to October. This is shown in the following table of the monthly imports for the years 1925, 1926 and 1927, showing the principal countries of consignment for the last two years.

TABLE LIX.—*Imports of Oranges and Mandarines into Switzerland.*
(In cwts.)

Imported from.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						1927.						
Spain	20,800	30,300	18,500	22,100	17,700	4,000	1,300	100	—	—	15,000	53,900
Italy	15,500	21,400	24,800	23,600	13,300	1,500	800	—	200	200	300	2,800
Algeria	700	300	100	—	—	—	—	—	—	—	300	1,400
Syria	—	300	—	—	—	—	—	—	—	—	300	200
South Africa ..	—	—	—	—	—	—	—	—	—	100	100	—
Total (1927) ..	37,000	52,300	43,400	45,700	31,000	5,500	2,100	100	200	300	16,000	58,300
						1926.						
Spain	26,000	32,400	38,100	27,900	18,100	9,900	1,100	100	200	—	6,300	46,700
Italy	8,500	17,100	20,900	20,600	9,700	5,300	2,000	1,600	300	700	600	6,400
Algeria	1,600	900	700	200	—	—	—	—	—	—	200	600
Total (1926) ..	36,100	50,400	59,700	48,700	27,800	15,200	3,100	1,700	500	700	7,100	53,700
Total (1925) ..	33,200	45,600	45,000	40,100	28,300	9,000	2,600	400	—	100	4,900	51,100

Czechoslovakia.

135. Considerable and increasing quantities of oranges are imported into Czechoslovakia, an average of 284,000 cwt. being received in the years 1925 to 1927, as compared with an average of 70,000 for the three years, 1922 to 1924. By far the greatest proportion of the total is consigned from Italy, and the quantity from Spain is very small by comparison.

136. The following table gives the imports for the six years ending 1927, and shows the quantities from the various consigning countries.

TABLE LX.—*Imports of Oranges into Czechoslovakia.*

Imported from.	1922.	1923.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Italy	59	69	65	237	241	231
Trieste	—	1	3	15	24	—
Hamburg	—	—	—	2	15	10
Spain	—	—	—	8	10	21
Austria	—	—	1	4	4	1
Germany	—	4	4	20	2	3
France	—	—	—	—	1	—
Arabia	—	—	—	—	1	—
Fiume	—	—	—	—	1	—
Other countries	2	1	1	—	—	2
Total	61	75	74	286	299	268

137. The main importing months are from December to June, the supplies during the remaining months from July to November being exceedingly small. The monthly quantities imported during 1926 and 1927 are shown in the following tables :—

TABLE LXI.—*Imports of Oranges into Czechoslovakia.*
(000 cwt.)

Imported from.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						1927.						
Italy	15	51	67	46	24	8	1	—	—	—	2	17
Spain	1	2	3	5	4	—	—	—	—	—	—	5
Other countries ..	4	2	3	1	2	2	—	—	—	1	1	2
Total ..	20	55	73	52	30	10	1	—	—	1	3	24
						1926.						
Italy	25	32	74	47	33	10	1	—	—	—	—	20
Spain	1	—	1	3	3	2	—	—	—	—	—	1
Trieste	3	5	10	5	—	—	—	—	—	—	—	—
Other countries ..	2	3	4	5	5	2	—	—	—	—	—	1
Total ..	31	40	89	60	41	14	1	—	—	—	—	22

138. Fair quantities of mandarines are also imported, principally from Italy and Spain, the total imports for the four years 1924–27 and the various countries of consignment being shown below :—

TABLE LXII.—*Imports of Mandarines into Czechoslovakia.*

Imported from.	1924.	1925.	1926.	1927.
	Cwt.	Cwt.	Cwt.	Cwt.
Italy	8,740	10,340	13,630	12,170
Spain	—	950	4,360	9,510
Trieste	360	1,070	2,160	20
Hamburg	20	—	1,210	380
Germany	90	80	140	20
France	—	80	140	250
Austria	270	420	120	270
Greece	—	—	20	—
Great Britain	10	10	—	—
Other countries	—	10	—	20
Total	9,490	12,960	21,780	22,640

139. The principal months of imports are from December to March as is shown in the following table of the monthly imports for 1926 and 1927.

TABLE LXIII.—*Imports of Mandarines into Czechoslovakia.* (Cwt.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						1927.						
Italy	3,070	4,920	2,420	—	60	—	—	—	—	—	100	1,590
Other countries	1,850	770	—	—	—	—	—	—	—	—	920	6,930
Total	4,920	5,690	2,420	—	60	—	—	—	—	—	1,020	8,520
						1926.						
Italy	4,800	3,290	960	220	20	590	20	—	—	—	40	3,660
Other countries	1,440	880	200	370	—	—	—	—	—	—	—	5,260
Total	6,240	4,170	1,160	590	20	590	20	—	—	—	40	8,920

Norway.

140. Oranges are not separately distinguished in the Trade Returns of Norway, being grouped with lemons. Consumption of these two fruits is steadily increasing and the total imports in 1927 showed an advance of 82 per cent. on the 1913 figures. The following table gives the imports from the principal countries of consignment for the years 1922–26 in comparison with 1913 :—

TABLE LXIV.—*Imports of Oranges and Lemons into Norway.*

Imported from.	1913.	1922.	1923.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Spain	64	159	225	176	202	215	—
Italy	10	10	11	11	10	13	—
U.S.A.	—	—	1	—	1	1	—
Germany ..	29	15	14	7	11	19	—
Great Britain ..	41	13	12	8	11	7	—
Denmark ..	1	1	1	4	1	2	—
Netherlands ..	3	3	—	—	—	—	—
Total.. ..	148	201	264	206	236	257	269

141. The principal months in which the fruit is imported are from December to April; supplies from July to November, especially from August to October, are small. The following table shows the monthly imports for the three years 1925 to 1927 :—

TABLE LXV.—*Imports of Oranges, Lemons, etc., into Norway.*

Month.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.
January	43	42	38
February	37	38	39
March	45	46	55
April	24	22	29
May	16	32	10
June	15	14	15
July	3	5	11
August	2	2	3
September	1	1	2
October	1	1	2
November	2	2	3
December	47	52	62
Total	236	257	269

Sweden.

142. Increasing quantities of oranges are being imported into Sweden, the total for 1927 being 247,000 cwt., as compared with 173,000 cwt. in 1922 and 123,000 cwt. in 1913. Spain and Italy send the bulk of the supplies but considerable quantities are re-exports from Germany, Denmark and the United Kingdom.

143. The imports for the five years ended 1926, compared with 1913, and the countries of consignment, are shown below :—

TABLE LXVI.—*Imports of Oranges into Sweden.*

Imported from.	1913.	1922.	1923.	1924.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Spain	32	79	63	68	87	95	—
Italy	39	33	49	64	51	84	—
U.S.A.	—	—	—	—	—	2	—
Germany ..	36	40	34	11	27	27	—
Denmark ..	4	15	20	14	14	11	—
Great Britain ..	11	6	5	3	4	3	—
Norway ..	1	—	1	—	—	—	—
Other countries	—	—	—	1	2	1	—
Total ..	123	173	172	161	185	223	247

144. The chief months in which oranges are imported are from December to June, and small quantities only are received from July to November. The following table gives the monthly imports for the three years 1925 to 1927 :—

TABLE LXVII.—*Imports of Oranges into Sweden.*

Month.	1925.	1926.	1927.
	000 cwt.	000 cwt.	000 cwt.
January	25	28	32
February	31	31	44
March	32	44	49
April	28	32	30
May	21	26	20
June	9	14	15
July	1	2	3
August	—	1	1
September	—	1	2
October	—	1	1
November	1	—	1
December	37	43	49
Total	185	223	247

Irish Free State.

145. Considerable quantities of oranges are consumed in the Irish Free State, and the yearly average imports for the three years ended 1927 have been 170,000 cwt. Most of this quantity represents re-exports from Great Britain and Northern Ireland but substantial amounts are imported direct from Spain and small quantities from Italy. The following table shows the imports by countries for the four years 1924–27.

TABLE LXVIII.—*Imports of Oranges into the Irish Free State.*

Imported from.	1924.	1925.	1926.	1927.
	000 Cwt.	000 Cwt.	000 Cwt.	000 Cwt.
Great Britain	103	108	116	126
Northern Ireland	11	12	14	10
Spain	52	43	37	41
Other countries	4	—	3	—
Total	170	163	170	177

146. The main importing months are from December to July, the period from August to November receiving comparatively small amounts. The monthly imports for 1926 and 1927 are as follows :—

TABLE LXIX.—*Imports of Oranges into Irish Free State.*

Month.	Imports in.	
	1926.	1927.
	000 cwt.	000 cwt.
January	22	20
February	16	16
March	22	24
April	20	26
May	17	15
June	21	19
July	17	10
August	6	6
September	3	4
October	2	3
November	3	9
December	21	25
Total	170	177

Denmark.

147. The Danish market for oranges does not appear at the moment to be expanding. The quantity imported during each of the years 1925 and 1926 was uniform at about 177,000 cwt. and in 1927 showed a fall to 155,000 cwt., as compared with an average of 184,000 cwt. for the four previous years. The yearly import is, however, much in excess of the pre-war figure, the average for the five years ending 1927 being 178,000 cwt. as compared with an average of 73,000 cwt. for the two years 1912 and 1913, an advance of nearly 150 per cent.

148. Spain is the principal country whence oranges are imported, but large quantities are also received from Italy. Spain has increased in relative importance as a direct source of supply, as 54 per cent. of the total imports in 1926 were consigned from Spain and 36 per cent. from Italy, as compared with 32 per cent. from Spain and 36 per cent. from Italy in 1913. The proportion of imports

which represent re-exports from Germany and Great Britain was, however, higher in 1913, and it is not possible to state the origin of these.

149. The following table shows the total imports of oranges and mandarines into Denmark, and the quantities from the various consigning countries for the six years ending 1926 in comparison with the years 1912 and 1913.

TABLE LXX.—*Imports of Oranges and Mandarines and the like into Denmark.*

Imported from.	1912	1913	1921	1922	1923	1924	1925	1926	1927
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Spain ..	19	23	123	108	116	129	120	95	—
Italy ..	27	26	41	40	39	56	44	64	—
Germany	10	11	9	23	34	6	10	11	—
Gt. Brit.	14	10	6	2	1	2	2	5	—
Other countries	4	2	2	—	—	—	1	1	—
Total	74	72	181	173	190	193	177	176	155

150. A fair proportion of the imports are re-exported principally to Sweden, as shown in the following table of re-exports for the six years ending 1926 :—

TABLE LXXI.—*Re-exports of Oranges and Mandarines and the like from Denmark.*

Re-exported to.	1921.	1922.	1923.	1924.	1925.	1926.
	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.
Sweden	4,720	4,800	6,020	9,430	13,600	10,770
Germany	—	70	3,150	14,300	—	1,740
Norway	70	530	490	2,840	630	3,050
Finland	—	10	200	—	740	—
Other countries	620	100	300	650	1,350	1,310
Total	5,410	5,510	10,160	27,220	16,320	16,870

151. The main importing months are from December to June, the remaining months from July to November, receiving small quantities only. The monthly imports for 1926 and 1927 are as follows :—

TABLE LXXII.—*Imports of Oranges into Denmark.*

Month.	1926.	1927.
	000 cwt.	000 cwt.
January	22	16
February	28	25
March	33	27
April	17	21
May	23	11
June	9	7
July	2	1
August	1	1
September	—	—
October	—	1
November	—	1
December	41	44
Total	176	155

Hungary.

152. Imports of oranges into Hungary were much heavier in 1927 than in the previous year, the total for the first quarter in 1927 having exceeded the 152,000 cwt. for the whole year 1926. Practically the whole of the supplies are from Italy, and are imported mainly in the first half of the year, while the quantity in the third quarter is very small indeed. Presumably the bulk of the imports in the last quarter of the year are received in December, as is the case with other European countries. The quarterly imports for the years 1926 and 1927 are shown in the following table :—

TABLE LXXIII.—*Imports of Oranges and Mandarines into Hungary.*

Imported from.	1st quarter.	2nd quarter.	3rd quarter.	4th quarter.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.
		1927.		
Italy	158	49	—	25
Other countries	2	2	—	7
Total	160	51	—	32

TABLE LXXIII.- *Imports of Oranges and Mandarines into Hungary.* —continued.

Imported from.	1st quarter. 000 cwt.	2nd quarter. 000 cwt.	3rd quarter. 000 cwt.	4th quarter. 000 cwt.
	1926.			
Italy	105	28	—	14
Other countries	3	1	—	1
Total	108	29	—	15

Yugo-Slavia.

153. The principal source of supply of imports of oranges into Yugo-Slavia is Italy, as is shown by the following table of imports during 1927.

TABLE LXXIV.—*Imports of Oranges into Yugo-Slavia,* 1927.

	000 *cwt.*
Italy	108
Greece	3
Austria	1
Other countries	1
Total	113

Russia.

154. Small quantities of oranges are imported annually into Russia, a large proportion being supplied by Turkey, and the remainder mostly by Italy. The total imports of oranges and mandarines in 1926–27 were 39,000 cwt. as compared with 58,000 cwt. in 1925–26.

Finland.

155. Increasing quantities of oranges are imported annually into Finland, mainly from December to June. Total imports for 1927 amounted to 69,000 cwt., as compared with 72,000 cwt. in 1926. The following table shows the monthly imports for the two years ended 1927.

TABLE LXXV.—*Imports of Oranges into Finland.*

Month.	1926.	1927.
	000 cwt.	000 cwt.
January	5	7
February	9	11
March	19	18
April	18	13
May	9	7
June	4	4
July	2	2
August	—	1
September	—	—
October	—	—
November	—	—
December	5	5

Canada.

156. Imports of oranges into Canada are practically all from the United States, as is shown in the following table of imports for the years 1925–26 and 1926–27.

TABLE LXXVI.—*Imports of Oranges into Canada.*

Imported from.	1925–26.	1926–27.
	Thousand boxes.	Thousand boxes.
United States	1,617	2,144
United Kingdom	5	9
Japan	81	94
Spain	11	5
Italy	3	7
Hong Kong	1	1
Jamaica	7	2
Other British West Indies	1	—
Mexico	3	—
Australia	1	—
Porto Rico	—	1
Total	1,730	2,263

Prior to the year 1926 imports of oranges were shown only by value in the Trade Returns.

CONCLUSION AND SUMMARY.

157. Within the past few years the world's commercial production of oranges has made very rapid strides, and the problem of disposing of the crop at a price remunerative to the grower is becoming increasingly difficult. Although definite information is lacking, there is evidence to show that Spain, the world's largest exporter, is likely to increase still further her contribution to the world's supply. Production in the United States is likely to increase very substantially within four or five years, as recent plantings come into full bearing and the yield in Florida recovers. In Italy, although the acreage under oranges is expanding but slowly, there is at any rate no retrograde movement, and recent regulations regarding export standards may be expected ultimately to increase the exportable surplus of quality fruit. In South Africa and in Palestine, plantings in recent years have been extensive, and production is likely to double itself within a few years, and to continue to increase thereafter, with an exportable surplus within the next decade several times as great as current figures. In the British West Indies, although no appreciable increase is recorded in recent exports, there are signs of renewed interest in citrus cultivation. Australian production is growing year by year. Japanese production and exports have shown an increase in recent years, and may increase further. Cyprus is gradually feeling its way towards a wider market for the oranges it produces in considerable quantities. The countries of South America, many of them large producers of oranges, are similarly turning their attention to markets outside the confines of their own continent, and large exports to Europe, especially from Brazil, may be looked for within a few years. Other producing and exporting countries, which serve only limited markets, such as Algeria, Portugal, Turkey and Greece, are maintaining their exports, and new countries which may have to be considered in the future are the colonies in East and West Africa.

158. The development of exports from certain exporting countries in recent years can be seen in the following table, which shows exports from 1922–26, with comparative figures for 1911–13, where available.

TABLE LXXVII.—*Exports of Oranges (including Mandarines) from certain Countries,* 1922–26.

Exported from.	Thousands of cwt.					
	Average 1911–13.	1922.	1923.	1924.	1925.	1926.
Spain	10,328	7,890	9,070	12,610	14,060	14,110
Italy	2,421	1,710	1,600	2,430	2,840	2,670
U.S.A.	804	962	1,598	1,786	1,380	1,875
Palestine	900	863	1,109	1,310	1,301	1,315
South Africa	14	186	203	311	471	403
Jamaica	—	58	70	57	74	87
Australia†	34	53	73	41	57	114
Algeria	204*	396	222	422	350	620
Japan	246	237	258	193	257	342
China	362	233	165	267	162	161

* Includes lemons. † All citrus fruits ; year ended 30th June.

159. Exports from the above countries, in spite of individual setbacks, have progressed year by year since 1922, and in the three years 1924–26 were round about 20,000,000 cwt. per annum, or from 60 to 70 per cent. above the 1922 level, and fully one-third greater than before the war. Although complete figures for 1927 are not yet available for all the above countries, the evidence shows that a further substantial increase occurred in that year.

160. The problem of disposing of the increasing supplies produced within these countries is now engaging the attention of growers' organisations everywhere. In countries such as the U.S.A., Australia and South Africa, and some of the smaller producers where domestic consumption absorbs a large proportion of the total crop, efforts are being made to stimulate home consumption, in addition to finding further outlets abroad. The introduction of mechanical contrivances for juice extraction for the preparation of fruit drinks for immediate consumption is stated to have had striking results in increasing the consumption of oranges and other citrus fruits in the U.S.A., Canada, and Australia. About 56,000 extractors are stated to have been

issued by the California and Florida Fruit Growers' Organisations, and it is estimated that these account for about 3,000,000 boxes of fruit (equivalent to about 2,000,000 cwt.) annually. Similar extractors have been introduced into Australia, South Africa, and New Zealand, and the possibility of extending their use in other countries (where, however, the machines would be dealing with imported instead of home-produced fruit) appears worthy of consideration.

161. Apart from such contrivances for the processing of oranges to provide juice drinks, there appear to be possibilities in the commercial production of orange juice and pulp for export. There are difficulties in the way of development in this direction connected with the keeping quality of the juice when shipped in bulk, but the solution of the transport problem would be likely to open up an extensive market for the product in both tropical and temperate climates. A further suggestion has recently been put forward in California of the utilisation of " cull " oranges in the manufacture of " marmalade juice " and " orange juice " suitable for the preparation of marmalade and jelly.

162. The chief consuming markets for the world's exportable surplus are at present, and will for many years continue to be, the European countries. Canada, where consumption has increased rapidly in recent years, is a natural outlet for the U.S.A. surplus, and imports also to a lesser extent from Japan and the West Indies ; New Zealand obtains the bulk of its requirements from Australia and from the Cook Islands, although U.S.A. oranges are also reaching this market. China, itself an important producer, provides a market for the greater part of the Japanese surplus ; and those South American countries which do not produce sufficient oranges for their own needs are in the main dependent upon the produce of adjacent territories. But Europe takes the bulk of the exports from all other important producing countries, and an increasing proportion of the U.S.A. surplus, and is now starting to take appreciable quantities from South America.

163. In certain countries of Europe consumption of oranges has made substantial progress within the past few years. Imports of oranges into a number of the chief countries in the five years 1922–26 are shown in the following table :—

TABLE LXXVIII.—*Imports of Oranges and Mandarines into the Chief Importing Countries.*

Imported into.	1922.	1923.	1924.	1925.	1926.
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
United Kingdom ..	6,880	7,462	7,240	7,513	7,772
Germany	375	268	3,082	4,108	3,743
France*	2,018	2,688	3,017	2,695	2,760
Poland	175	154	442	444	123
Switzerland	222	237	256	260	305
Norway*	201	264	206	236	257
Sweden	173	172	161	185	223
Czechoslovakia ..	61†	75†	83	298	321
Denmark	168	179	165	160	159
Austria	68	—	252	314	314
Belgium*	—	607	699	531	671
Irish Free State ..	—	—	171	163	170
China	—	187	176	250	366

* Includes lemons.

† Excluding small quantities of mandarines, of which 9,000 cwt. were imported in 1924.

164. From a total of less than 11,000,000 cwt. in 1922 imports into these countries have increased to 16,000,000 cwt. in 1924 and to about 17,000,000 in 1925 and 1926. A further increase may be looked for, but it is perhaps doubtful whether the prospective increase in the exportable surplus from producing countries can be fully absorbed by these countries unless consumers are enabled to purchase the fruit at lower prices than those now current. The increasing competition among producing countries seems likely to raise the general standard of quality of export fruit, and this would clearly result in limiting the volume of exports, but this means increasing the quantities of cull fruit, for which some profitable use must be found, either in the production of orange juice and pulp for export, or in other ways, such as oil production, cattle feed, etc.

165. That there is room for a considerable expansion in the consumption of raw oranges (aided, perhaps, by the " extractors," to which reference has been made above) is hardly open to doubt.

Approximate calculations, based upon production, imports and exports, show that even in the United States consumption per head of the population amounted in 1926–27 to only about 23 lb., or little more than one orange per week. In Australia, Canada and the United Kingdom, consumption is slightly less, at about 19 or 20 lb. per head, and no other European country consumes one-half this amount per head. Estimated annual consumption per head is shown below :—

TABLE LXXIX.—*Consumption of Oranges.*

Country.	lb. per head.	Country.	lb. per head.
U.S.A.	23	France	7*
Australia	20	Irish Free State ..	6
United Kingdom ..	19	Denmark	5
Canada	19	Austria	5
New Zealand ..	12	Sweden	4
Norway	10*	Czechoslovakia ..	3
Belgium	10*	Hungary	2
Switzerland ..	9	Poland	½
Germany	7		

* Including lemons.

166. *Import Duties.*—One obstacle to the increased consumption of oranges in many European countries is to be found in the duties imposed upon imports, and the removal of these tariffs would undoubtedly stimulate consumption and help to solve the problem of disposing of the world's surplus. The recent removal of the import duty on oranges in Estonia has been followed, it is reported, by a rapid increase in consumption. The tariffs on imported oranges in certain countries are shown below, with conversions at the current rate of exchange :—

TABLE LXXX.—*Import Duties on Oranges.*

United States	1 cent (½*d.*) per lb.
Canada	Free.
United Kingdom	Free.
Belgium	5 francs (7*d.*) per 100 kilogs. 80 francs per 100 kilogs. on packages of 5 kilogs. or less. Also 2 per cent. *ad valorem* turnover tax.

TABLE LXXX.—*Import Duties on Oranges.*—continued.

Switzerland	10 francs (8*s.*) per 100 kilogs.
Italy	2 gold lire (1*s.* 7*d.*) per 100 kilogs.
Germany	2·50 Reichemarks (2*s.* 5*d.*) per 100 kilogs.
France	35 francs (5*s.* 8*d.*) per 100 kilogs. on Palestine, Spanish, United States and Italian oranges. 70 francs per 100 kilogs. on South African oranges. 50 francs per 100 kilogs. on mandarines. Also turnover tax 2 per cent. *ad valorem.*
Austria	6 gold krone (5*s.*) per 100 kilogs., also 6 per cent. *ad valorem* turnover tax.
Yugo-Slavia	5 gold dinars (4*s.*) per 100 kilogs. (If paid in paper currency, the rate is raised 11 times.)
Finland	75 Finnish marks (7*s.* 9*d.*) per 100 kilogs.
Norway	2 kroner (2*s.* 3*d.*) per 100 kilogs.
Czechoslovakia	60 krone (7*s.* 4*d.*) per 100 kilogs. on oranges. 90 krone per 100 kilogs. on mandarines. Also luxury tax 17 per cent. on total value plus tax plus transport.
Denmark	6·5 kroner (7*s.* 3*d.*) per 100 kilogs.
Sweden	10 kroner (11*s.* 1*d.*) per 100 kilogs.
Hungary	6 gold kroner (5*s.*) per 100 kilogs., also 13 per cent. *ad valorem* luxury tax.
Poland	206·40 zloty (£4 15*s.*) per 100 kilogs. plus 10 per cent.
Lithuania	150 lits (£3 2*s.*) per 100 kilogs.
Latvia	100 or 150 lats (£4 or £6) per 100 kilogs., also surtax 15 centimes per 10 lats.
Estonia	Free.*
Turkey	2,025 piastres (£2 3*s.*) per 100 kilogs., also 6 per cent. *ad valorem* transaction tax.
Bulgaria	30 gold levas (£1 4*s.*) per 100 kilogs., also octroi tax of 10 gold levas per 100 kilogs. If paid in paper currency, these rates are increased 20 times.
Netherlands	Free.
Rumania	8 gold lei (6*s.* 4*d.*) per 100 kilogs., also port tax of ½ per cent. *ad valorem,* also turnover tax 24 paper lei (7*d.*) 100 kilogs. If paid in paper currency, 320 lei (8*s.*) per 100 kilogs.

167. So far as Empire orange supplies are concerned, the two chief exporting countries are at present South Africa (including Rhodesia) and Palestine, with Australia, West Indies and Cyprus shipping smaller quantities. Palestine, Cyprus and the West Indies supplies

* Duty removed 5th June, 1928.

are available in the same seasons as the Spanish and Italian fruits, and have naturally to meet the most intense competition. The Palestine shippers have recently exploited new markets in Central Europe, and are investigating the possibility of finding new outlets in South America. As regards South African oranges, and also Australian, if and when these come forward in large quantities, the season overlaps only at either end with the Spanish season, although the latter may ultimately be extended by the planting of later varieties. European demand for oranges in the summer months, when South African supplies are on the market, is affected by the supplies of domestic fruits. In addition, shipments from the United States are at their maximum in these months, and South American supplies, should they become important, will also fall in this period. At the same time, the summer consumption of oranges is very small everywhere in Europe, and particularly so outside the United Kingdom. In the following table are shown imports of oranges into certain European countries in the four months, July to October, in the year 1926, with the percentage of these to total imports for the year.

TABLE LXXXI.—*Imports of Oranges, July to October,* 1926.

Country.	Imports, July to October.	Percentage of imports for year.
	cwt.	Per cent.
United Kingdom	743,000	9
Germany	57,400	1½
France	193,000†	7†
Poland	1,400	1
Switzerland	6,000	2
Norway	7,800†	3†
Sweden	4,800	2
Czechoslovakia	1,700	0·5
Hungary	400*	0·3*
Denmark	3,300	2
Austria	850*	0·3*
Belgium	21,600†	3†

* July to September. † Includes lemons.

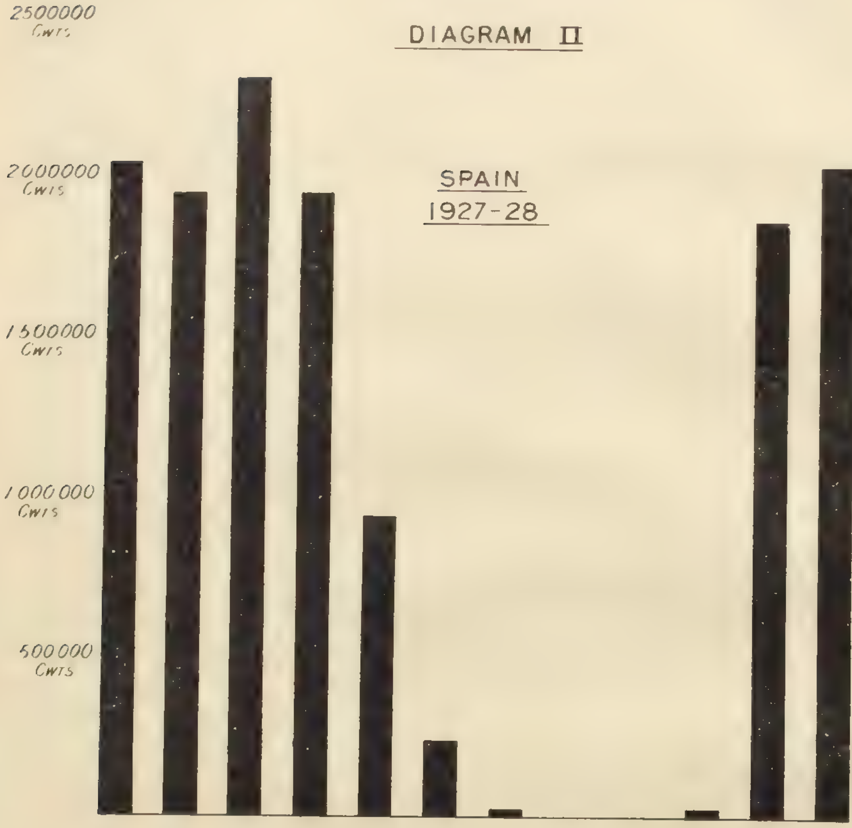
168. Of the world's largest exporting countries, only the United States exports oranges during the late summer and autumn months, and exports from that country are falling off from June to November. South Africa and South America, which both export during these months, are likely to increase rapidly in importance, but their exports in the aggregate are at present only small compared with those of Spain, Italy, the United States and Palestine. In diagram II on the next page are shown monthly exports from the five largest orange exporting countries, clearly revealing the predominance of the months from November to April in the world's orange supplies.

169. It has already been shown that there is room for expansion in orange consumption in European countries generally. The above figures show that orange consumption in the summer months is practically negligible, and suggest that eventually a market for the increasing production of South Africa, Australia, the U.S.A., and South America, may be found in these countries. It is largely a matter, however, of regular supplies at a price which consumers are able and willing to pay. In most European countries there are more or less plentiful supplies of home-produced fruit available, and consumers have a choice of fruits at fairly low prices. The improvement in the economic condition of Europe should, however, facilitate the sale of imported luxury fruits, among which summer oranges may be classed, although in view of the prospective increase in supplies in the near future, it would be hazardous to prophesy that the whole of the summer surplus a few years hence will be disposable at the price levels of recent years.


MONTH
FR
2500000.
Cwts.

MONTHLY SHIPMENTS OF ORANGES FROM CERTAIN COUNTRIES

DIAGRAM II



TOTAL EXPORTS IN 1926 — 14 114 000 Cwts

TO U K	50 per cent	7 117 000 "
" OTHER EUROPE	50 " "	6 997 000 "

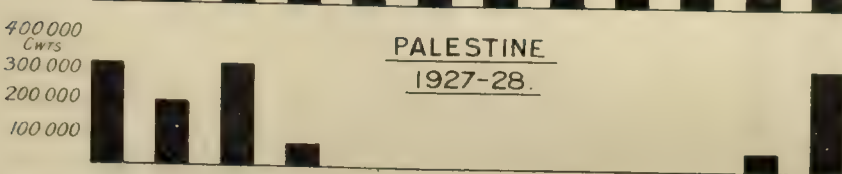
(NOTE - Diagram represents shipments during Season 1927/28, excluding exports by rail across the French-Spanish border)

TOTAL EXPORTS IN 1927 — 3 071 000 Cwts

TO U K	2 per cent	72 000 "
" OTHER EUROPE	98 " "	2 999 000 "

TOTAL EXPORTS IN 1926-27. — 2.260.000. Cwts

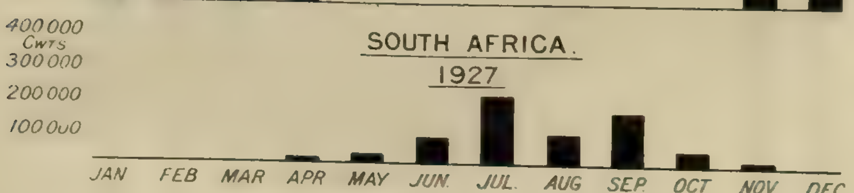
TO U.K.	17 per cent.	380.000 "
" CANADA	74 " "	1690 000 "
" OTHER COUNTRIES	9 " "	190.000 "



TOTAL EXPORTS IN 1927-28 — 1 250 000 Cwts

TO U.K	86 per cent	1 080 000 "
" OTHER EUROPE	14 " "	170 000

(NOTE - Shipments exclude consignments to Egypt)



TOTAL EXPORTS IN 1927. — 468.000. Cwts

TO U.K.	99·8 per cent	467 000.
" OTHER COUNTRIES	0·2 " "	1.000.

E.M.B. 16

REPORT ON DEVELOPMENT OF AGRICULTURE IN BRITISH HONDURAS

By
H. C. Sampson, C.I.E.,
Economic Botanist,
Royal Botanic Gardens, Kew

MAY, 1929

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller.
1929.
Price 1*s.* 6*d.* Net.

70-221-16.

CONTENTS.

(35476) Wt. P2429/545/1711 1000 4/29 Harrow G.3

Letter from Dr. A. W. Hill, C.M.G., F.R.S., Director, Royal Botanic Gardens, Kew, covering Mr. Sampson's Report.

16th February, 1929.

Sir,

I have the honour to enclose herewith Mr. H. C. Sampson's Report on his recent visit to British Honduras which was undertaken, with the concurrence of your Board, on the invitation of His Excellency the Governor and at the request of the Rt. Hon. the Secretary of State for the Colonies.

In submitting his report I desire to call attention to some of the more important points which are considered.

Mr. Sampson's report indicates very clearly the necessity that exists for the creation and development of a local Agriculture, since the country can no longer continue to expand by depending solely on the exploitation of its natural resources.

The steps he has recommended to be taken, namely, the establishment of Agricultural Stations where trials with different crops, methods of cultivation and the economics of crop production can be studied, are I consider, sound and must form the basis for any real and sound progress. I venture to emphasise, therefore, that it is essential, if the best use is to be made of the services of the newly-appointed Agricultural Officer, to ensure the placing at his disposal of ample funds for starting such work, and I would also add that, since he is single handed, he should receive all the help possible from the Forest Department, which is the only other technical service in the Colony.

Any agricultural development which may take place cannot be built up in a day. The report clearly indicates that local soil conditions preclude large scale undertakings and that the future of the Agriculture of the country must be based on the foundation of peasant holdings and small-scale farming. This will naturally take time in a country where there is little or no agricultural tradition, and where the knowledge of what crops can be economically grown has yet to be investigated.

Mr. Sampson has made reference to many of the difficulties that exist in the way of making such a system of agriculture possible, and the greatest of these seems to be that of making available land

on suitable terms between landlord and tenant so that a permanent Agriculture built up on a sound basis can be established. It is hoped that the Government will be able to find a satisfactory solution to these difficulties.

On the question of developing transport facilities I consider Mr. Sampson has taken a wide and sound view. He is insistant that any development which the Government is able to effect should be for the present, the improvement of existing facilities rather than in the launching out into new and costly schemes which are of doubtful assistance to Agriculture. He has made it clear that the first step in improving transport facilities must be to assist the producer. For it is only by this means that the revenue of the Colony can be expected to increase and so furnish funds for any further and new developments which may in course of time be indicated.

I am, Sir,

Your obedient Servant,

ARTHUR W. HILL,
Director.

The Secretary,
Empire Marketing Board,
2, Queen Anne's Gate Buildings,
S.W.1.

REPORT ON DEVELOPMENT OF AGRICULTURE IN BRITISH HONDURAS.

I. INTRODUCTION.

THE following terms of reference were supplied to me by His Excellency, Sir John Burdon, The Governor of British Honduras.

> " To consider and report on the prospects of agriculture in the Colony and the means by which agricultural development might be fostered by Government."

If I have exceeded these terms of reference, it has been done in the interests of the Colony : for it is not always possible to say where and in what manner Government action will assist or retard progress.

I wish to take this opportunity of thanking His Excellency, Sir John Burdon, as well as Mr. E. W. Evans, who was acting for him when I arrived in the Colony, for the ready and generous assistance which they and other officers of the Colony rendered to me during my stay there, as well as for the personal interest which they took in my enquiry.

II. ITINERARY.

I arrived at Belize on the evening of August 17th, and on Monday the 20th and the following day made a short tour along the lower reaches of the Belize River as far as Boom. H. E., the acting Governor, the Conservator of Forests, and Mr. Stocker accompanied me. From here we crossed a pine ridge to Mussel Creek, and crossing this followed up for some distance the trail to Scotland, which is on the banks of the Belize River above Little Falls. From here we returned to Belize.

On August 23rd, in company with Mr. Evans, the acting Governor, Mr. Oliphant, the Conservator of Forests, and Mr. Stocker, who has been doing duty as Agricultural Officer, I started on a tour across the colony to the Guatemalan frontier. Our first objective was Hillbank,

which we reached, travelling first by launch up the Belize River to Isabella, from there on horseback to New River Lagoon and again by launch on to Hillbank. Here we had an opportunity of seeing some of the clearings made round Mahogany camps, and also of seeing the land adjoining the logging railway of the Belize Export and Produce Company, which connects the New River Lagoon with Sierra d'Agua. On Monday, August 27th, we left by trolley for Sierra d'Agua and from there on horseback for Yalbak, an Indian village a few miles beyond San José. Continuing the following day we again struck the Belize River at Happy Home. From there on along the riverside pastures to Banana Bank where we spent two days visiting other riverside properties. From here we travelled up the river by launch to Cayo and on from there by motor to Benge, where we again took horses and rode to Camp 6. This was made our headquarters for two days, and we visited the Great Southern Pine Ridge to see what were the prospects of opening up cattle ranching there. A magnificent view was obtained from South View Point, which overlooks all the unexplored territory of the Maya Mountain region with the Cockscomb Mountains in the distance. On the morning of September the 4th, we left Camp 6 by the logging railway, belonging to the Mengel Company, for Vaca Falls and walked down a magnificent limestone gorge to Flour landing, from where we travelled down the Belize River to Cayo by "pitpan," and on from there the same evening by launch to Belize, which we reached at 11 a.m. on September 5th.

My second tour was to the south of the colony, on which I was accompanied by Mr. Oliphant and Mr. Stocker. This extended from September 10th to September 25th, during which time we visited the Stann Creek Valley, Placentia, the Sittee River, up which we travelled as far as Kendal, the Monkey River, of which we were only able to see the delta portion owing to the high floods in the river, the Deep River, the Rio Grande, up which we travelled as far as Waterous' landing on the Columbia branch. Here we visited San Antonio and other Indian settlements. We also visited Punta Gorda and the Toledo Settlement as well as Barranco, a Carib village on the coast near the mouth of the Temash River, which we travelled up a short distance.

The third and final tour was to the north of the colony, and this extended from October 1st to October 9th. This was confined to the marl and limestone country between the coast and the New River,

except for visits to the cane and coconut areas in the neighbourhood of Corosal. Travelling north to Corosal, we visited Salt Creek Lagoon, Northern River and Sarteneja. From Corosal we travelled up the New River to San Estevan, and from there rode out to the Fresh Water Creek Forest Reserve ; from here we rode to Honey Camp and thence to Orange Walk, returning down the river again and back to Belize.

Besides these extended tours I was able, while remaining at Belize to visit the Burdon Canal, which is at present being constructed across the swamps behind Belize with the object of joining up the Belize and the Sibun Rivers. I spent two days travelling up the Sibun River as far as Gracie rock and back, and two days visiting the Turneffe Cays, where I was able to see the coconut plantations, which Government recently acquired, and which they have since leased out, as well as the most interesting research work, which is being carried out by Dr. Crawshay in attempting to resuscitate the sponge industry which once existing within the lagoons of this group of cays.

III. CLIMATE.

The climate of British Honduras may be described as tropical in the south and sub-tropical in the north. Meteorological records are, however, very meagre and incomplete. The rainfall in the north and west is comparatively low and the air in consequence is comparatively dry. In the north and west there are six to seven months of dry weather when the rainfall varies from 10 to 14 inches during this period, while in the remaining five to six months, when the rains are expected, the rainfall varies from about 25 to 40 inches.

At Belize and in the south of the colony there is a much shorter dry season which extends for only four months, from February to May, when the rainfall varies from about 8 to 18 inches. The June-September rainfall increases as one goes further south, averaging 27 inches at Belize, 34·5 inches at Middlesex, in the Stann Creek Valley, and as much as 95 inches at Punta Gorda in the south. The October-January rainfall is fairly constant, increasing only slightly as one goes further south from 31 inches at Belize to 36 inches at Middlesex and 40 inches at Punta Gorda.

The only records of temperature which are now available in the colony are those relating to Belize. These show that the temperatures are fairly constant throughout the year, and also indicate that

humidity is high. The mean daily maximum varies from 75·43 in January to 86·07 in August, while the mean daily minimum varies from 66·97 in January to 77·00 in June. The highest maximum recorded during a period of seven years is 95 degrees in June, while the lowest minimum recorded during a period of ten years is 53 degrees in January. The low maximum temperatures again point to high humidity, and the low minimums are due either to continuous rains or to northerly gales, known locally as "Northers," which are experienced during the cold weather months. These severe drops in temperature are, however, very rare. Dunlop makes mention of one in his report when bananas in the Stann Creek Valley were damaged by a chill in 1916.

Humidity is not so high in the interior, and though there are no records to show this, one can notice the drop in humidity when one is travelling in the north and west. On the other hand, the humidity is very high in the Toledo district in the south, considerably higher than it is in Belize.

RAINFALL.

	Dry Season.				*Total*
	Duration.	*Rain-fall.*	*Duration.*	*Rain-fall.*	*Rain-fall.*
Corosal . . (Av. of 8 yrs.)	Nov.–May	13·24	June–Oct.	26·19	39·43
Cayo . . (Av. of 4 yrs.)	Dec.–May	11·08	June–Nov.	28·52	39·60
Orange Walk . (Av. of 10 yrs.)	Dec.–May	13·97	June–Nov.	37·59	51·56
Belize . . (Av. of 10 yrs.)	Feb.–May	8·54	June–Sept.	26·98	66·77
			Oct.–Jan.	31·25	
*Middlesex** . (Av. of 7 yrs.)	Feb.–May	10·12	June–Sept.	34·45	80·73
			Oct.–Jan.	36·16	
Punta Gorda . (Av. of 10 yrs.)	Feb.–May	17·80	June–Sept.	96·29	153·80
			Oct.–Jan.	39·71	

* Stann Creek Valley.

TEMPERATURES.

Average for three years 1925–27 (Belize).

Month.	*Mean Daily Max.*	*Extreme Max.**	*Mean Daily Min.*	*Extreme Min.*†
January . .	75·43	87	66·97	53
February . .	78·53	89	69·80	60
March . .	80·67	89	71·00	60
April . . .	82·63	92	76·00	64
May . . .	84·40	93·5	76·07	66
June . . .	85·33	95	77·00	68
July . . .	85·40	88·5	75·80	60
August . .	86·07	89	75·93	66·5
September . .	84·53	91	75·27	68
October . .	83·37	91·5	73·07	59
November . .	80·03	89·5	69·13	57
December . .	76·67	86	70·31	60

* In seven years. † In ten years.

IV. SOILS.

In general, soils suitable for permanent agriculture do not occur in large areas, and British Honduras must always be largely dependent on its forests for its prosperity ; for though many of the soils of the country are fertile, they are too shallow to be of value for permanent agriculture. They are capable, however, of proving to be of very considerable value from a forestal point of view. Mr. D. Stevenson, the Assistant Conservator of Forests, in his report on the Fresh Water Creek Crown Lands, has attempted to classify the different forest types represented in that area and a study of the various reconnaissance maps made by the Forest Department of the northern level marl and limestone country, shows that this classification is fairly typical of this part of the colony, except that it does not include any of the " Pine ridge " areas of the north. These pine ridge areas occupy approximately a quarter of the area of level country north of the Belize River. The classification of areas representing different types of forest, though only approximate, can be taken as fairly accurate and, as forest types represent soil types, the figures given are of great interest. The approximate area of these Crown lands at Fresh Water Creek Reserve is 14,400 acres. Of this area 3,000 acres

or 21 per cent. represent Savannah, or open grass land country, which is usually swampy. These soils usually consist of a sandy clay, and are leached in appearance ; 4,400 acres, or 31 per cent., represent " Acache " (stunted forest growth on swamp soils), and Broken Ridge cays (the lowest type of exploitable mahogany and sapodilla forest). These are yellow to black soils very shallow and often water logged, generally over-lying marl, occasional flint beds are to be seen. 6,000 acres, or 41 per cent., represents High Ridge, an intermediate type of forest represented by the Bay leaf palm (*Sabal excelsa* Morris). These are black soils usually only a few inches deep and overlying marl or limestone. 340 acres, or $2\frac{1}{2}$ per cent., of "wamil" (secondary forest growth on abandoned shifting cultivation) is chiefly on broken ridge and 660 acres, or $4\frac{1}{2}$ per cent., is Cohune Ridge. This last is what is termed a " Cohune cay," or island, and consists of an island of deep rich well-drained black soil well suited for permanent agriculture, overlying limestone or marl. Thus, out of this total area of 14,400 acres, only $4\frac{1}{2}$ per cent. is really good agricultural land. A certain portion of the " high ridge " area might be considered suitable for permanent agriculture in countries where there is pressure of population on the land and where labour is cheap, but in an undeveloped country such as this, though some of it is capable of being converted into pasture land, its only cultural value would be for shifting cultivation and then only selected portions if it would bring in a profitable crop return at the expense of what might be developed into valuable forest. Mr. Stevenson remarks about this Cohune cay or ridge as follows :—" The occurrence of this ' Corosalito ' (a Spanish name for a small Cohune cay, cf. Corosal), is interesting inasmuch as it forms one of a chain of isolated Cohune ridges, the others being those of Rancho and Lopez Creek in the Esteven property, and the Cocoa in Tower Hill East and the 99 years' lease." These chains of Cohune cays seems a common feature of this level country in the north, and, as their name implies, were seemingly at one time true cays or islands when that part of the country was under the sea. In fact, visiting the cays off the coast at the present time, one can almost envisage the formation of these different types of soil represented by the different types of forest now found growing on them.

The country on the western frontier is, in many respects, similar to that already described, except that at some time it has been raised from the level by earth movements. Instead of being flat country, it shows a tendency to be broken up into small ranges of hills with

intervening valleys. These earth movements have been greater in the south where, according to Ower's geological map of British Honduras, the hills rise to an elevation of over 2,000 feet, but towards the north they gradually tail off. At Cayo the elevation is about 600 feet, and further north the low broken country appears to extend as far east as Sierra d'Agua, in the neighbourhood of Ramgoat creek. In this undulating country one expects to find much more land suitable for agricultural development ; for the soil from the hill slopes collects in the intervening valleys and it is in these that what is termed Cohune ridge appears. In this part of the country the breaking up of the level surface by earth movements has apparently done much to remove the lower types of forest vegetation. The formation of hills and valleys has had the effect of improving the drainage and presumably soil denudation from the hills has masked in most cases types of soil, which in the north are classed as " acache " and savannah. Thus, in this area the main type is High Ridge with the lower and more fertile lands as Cohune Ridge. The Pine Ridge is represented by the Great Southern Pine Ridge, an elevated plateau rising, according to Ower, from 1,500 to 3,000 feet. This lies to the south-east of Cayo and covers an area of about 120 square miles. The surface of this area is mostly sand, and here the forest growth is practically pure Pine. In depressions and hollows where water collects one sees a change in the vegetation. Here the soil is heavier and better supplied with moisture, and the Pine has given place to broad leafed species mainly represented by Oaks. At least three species of Oak were found growing in these small damp hollows of what might be termed Broken Ridge. In these hollows also the ground vegetation, instead of being a sparse growth of deeply embedded tufted grasses, as is the case in the pine areas, is much more luxuriant and a marked feature of this is the dumb cane, *Tripsacum dactyloides L.*, which is usually found all over the colony where the Pine Ridge and the wet Broken Ridge adjoin. Apparently the Broken Ridge, which is generally wet and swampy, receives the drainage from the Pine Ridge which, at any rate on the surface, is usually dry and firm.

The great mountainous region of the south, which is practically all that remains to the colony in the way of Crown lands, has hardly been explored as yet on account of its inaccessibility, and though there are a few isolated areas represented by river valleys, which may ultimately be found of value for agricultural purposes, the greater portion of the area is worthless from an economic point of view.

Some of this area is known to contain supplies of valuable timber, but this is valueless owing to its inaccessibility. This area is only of interest, therefore, to this report, as it is from this mountain mass that all the rivers of the colony, except those which flow due north, have their origin, and it is from the weathering of the rocks which form this mass that the silt brought down by these rivers has been formed. These mountains, according to Ower, are sedimentary. They consist of the oldest geological formations in the country, being composed of slates, quartzite, sandstone and blue limestone with intrusive granite and porphory. The silt brought down by these rivers has been deposited on the banks, forming a natural levee rising on each side of the river to a higher level than the surrounding country. It is natural that the coarser soil particles will be deposited along the higher reaches of the river, where the current is swifter, and it is also natural that such deposits will be much greater than in the case of fine silt, much of which remains suspended and is carried out to sea. Where these rivers, therefore, come out on to the coastal plain one finds that in the upper reaches the river banks are usually high and wide, consisting of a free working sandy loam. It is these riverine lands which provide the most continuous and valuable agricultural soils of the colony, and it is these which in the first instance should receive attention. This does not necessarily imply that they are the best soils. Some of the "Cohune cays" in the north are probably much better, but the value of these riverine soils lies in the fact that they are well drained, and easily accessible, while river transport in one form or another, is available or can be made so. As these rivers approach the level of the coast the banks are much lower, the levee is narrower, and the soil is of a much closer texture. In most cases it is a very stiff sour clay—in some cases almost an indurated clay undergoing laterisation. It is on these heavy soils that the recent agriculture of the newly settled inhabitants seems to have made its beginnings, and it is owing to the cultivation of these stiff clays, rather than of the better class of soils found higher up the river, that much of the backward condition of the agriculture of the colony is due.

The soils just described are purely riverine soils, and in the upper reaches of the rivers are locally classed as Cohune ridge; for it is here that the Cohune palm flourishes. Nearer to the coast, where the soils are composed of stiff clays, no Cohune palm is to be found.

Behind the riverine strip is the natural drainage of the river levee and of the pine ridge country which lies in between two river systems. This in the wet season is usually swamp, though in the dry weather it is possible that this might be utilised for cultivation. The coastal pine ridge soils are usually sandy on the surface, but below show signs of laterisation. They are practically valueless for agriculture without very heavy manuring, and are decidedly acid.

In the extreme south of the colony there is yet another class of soils. According to Ower, these are much more recent soils, and the underlying rock formation consists of shales, calcareous sandstones, limestones and diatomites. These sedimentary rocks have been subjected to heavy crushing and fracturing. It is on this formation that the Toledo settlement has been formed. Sugarcane is really the only crop which is grown here, and it speaks well for the fertility of these soils, many of which are of no great depth, that cane is frequently ratooned for a period of twenty-five years. These soils are mainly stiff clays and appear to be acid. They vary greatly in depth from a few inches to a reasonable depth, while natural drainage is afforded by their lying directly on the broken and crushed rock strata below.

V. THE RESOURCES OF THE COUNTRY AND THEIR RELATION TO GOVERNMENT REVENUE.

The prosperity of British Honduras has in the past depended almost entirely on the exploitation of its natural resources in the shape of forest produce, and as long as the supply of and demand for these were ample, the colony was the most prosperous of all the British possessions in the Caribbean.

The three main forest products were Logwood, Chicle and Mahogany. Owing to the substitution of aniline dyes, the Logwood industry rapidly declined and is now quite insignificant, being valued in 1927 at £1,730. Chicle, which is the gum of *Sapota achras*, and which is one of the principal materials from which chewing gum is manufactured, is obtained by tapping the stem of the tree and collecting the latex or gum which exudes. There is no continuous flow of latex, as is the case with rubber, and the wound formed by tapping does not heal up and renew the bark at all readily. Trees can only be tapped at intervals of about three years and, as this tapping greatly weakens

the tree, it dies as a rule after the third tapping. It is a slow growing tree and up to very recently no attention at all has been paid to the possibilities of natural regeneration. Even if natural regeneration should prove to be successful, a long period must elapse before the young trees are sufficiently large to tap. There are several forms of *Sapota achras* which are recognised by the tappers, and it is only certain forms that are considered worth tapping, thus, not only are there very heavy casualties, but these are greatest in those trees of the type which give the greatest flow of gum and it can be readily understood that the industry is waning as the forests are being depleted. Since Chicle pays an export tax of so much a pound, this industry is a source of considerable revenue to Government.

The figures for export do not show any great decrease at the present time, since these include large quantities of Chicle collected in neighbouring territories, estimated by Dunlop in 1921 as 75 per cent. of the total, which up till lately have not been so heavily tapped as have the trees in the Colony. It is merely a matter of time, however, before the exports of this commodity must show a greater rate of decrease and one has only to travel through the forests on the limestone areas to see what a heavy mortality has already taken place in the Sapodilla forests. A tree which has not been tapped is a rarity and when one if found it is usually of a type which is known to the tappers as not likely to yield latex in payable quantities.

Mahogany is the third and most important forest product of British Honduras, and as this pays a stumpage royalty besides an export tax on the quantity exported, it is an important source of revenue to the Government. Before the war and after, until 1923, the annual export of Mahogany was fairly constant, in the neighbourhood of about 10 million superficial feet, but in the last four years this rate has increased with alarming rapidity from between 12 and 13 million in 1924 and 1925, to nearly 19 million in 1926 and nearly 25 million in 1927. The utilisation of mechanical transport has been largely responsible for this increase. Before its introduction the maximum economic lead, employing bullock power transport, was placed at eight miles from the felling place to the nearest river or stream by which it could be floated down to the coast. With the use of mechanical transport this distance has been increased to about a twelve mile lead, and with the laying down of light logging railways the distance has been further increased by the lead to the rail-head rather than to the river. The employment of tractors for logging

operations and of logging railways for conveyance to the rivers can only be used when operations are carried on on a much larger scale than that formerly adopted by the mahogany contractor using bullock transport alone, and it is clear that the tendency in the future will be for much more wholesale extraction than was the case a few years ago. Writing in 1883, Morris (now Sir Daniel Morris), gives the value of the Mahogany exports at that time as £50,000 a year. The value of the exports of this timber in 1927 is placed by the customs authorities at over £492,000 or nearly ten times that amount.

Constant reference in the literature concerning the Colony has been made to the supplies of Mahogany becoming exhausted. As long ago as 1789 a map of the Colony shows Mahogany forests in the region of the Belize River as being worked out. Similar statements have been made from time to time ever since, but the extraction of Mahogany has still continued and in increasing quantities. At first sight one might doubt these statements, but what has happened has been that the forests were for the time being depleted of trees of a size fit for extraction. In the meantime smaller trees have been growing up to this size and again these have been felled. It is the continuation of this process which is now being felt and it is evident that it cannot continue indefinitely. If all trees of a felling size are cut there can be no seed-bearing trees left, and the time must come, and in many places it has come, when there are no trees left to serve as seed bearers. Occasionally an old tree, considered useless for felling, has been left, which has acted as a seed bearer and there has been a little localised regeneration, but this is insignificant. The resuscitation of the stand of Mahogany in such forests is now only possible by artificial regeneration. The better the quality of the Mahogany land the worse is the position, because the age of maturity on good land is less than is the case on poor land, and the sooner is the stage reached when natural regeneration is no longer possible.

It is only within recent years that the country has had the opportunity of technical advice on forest problems. Until the Forest Department was created great ignorance prevailed in regard to forestry in general. A common belief, I understand, was that the regeneration of Mahogany was spontaneous, and the idea of the tree originating from a seedling was entirely novel.

As British Honduras was originally entirely a forest country and depended on the exploitation of its forest, both as a source of private enterprise and for Government revenue, one can understand how in the early days there was the temptation not only to give contracts freely for felling timber on Crown lands, but also to dispose of land in a wholesale manner to private owners, since in both cases trees which were felled paid their royalty to the Government. In fact, land in itself was considered of little value, what was thought to be of value was the timber which was growing on the ground. Unfortunately land was, until quite recently, disposed of unconditionally and the results of this are now being felt. Instead of the Government getting a royalty on timber felled throughout the Colony, they are getting a royalty on timber, which in the majority of cases was unexploitable till mechanical means of transport were adopted. From the more accessible areas very little of this form of revenue is being obtained. The only revenue which much of this land now produces, is from the existing land tax of three farthings an acre on freehold land, which for the whole colony brings in a revenue of something in the neighbourhood of £8,500 per annum, and since, with the exception of Pine Ridge areas and the mountainous inaccessible country in the south, practically the whole of the Colony has been alienated, there is not much opportunity to revise the conditions under which land is to be disposed of. Thus the land, where its timber resources have been exploited, is practically valueless to the country as a source of revenue. The landholder can retain this as long as he pays this nominal land tax—a matter of about £3 for every 1,000 acres—which in most cases he is prepared to do, since there is always a chance of making some money out of it for nothing, such as fees for right of way, subleasing for " milpa " cultivation or even the killing of a few head of game for sale on the market, while there is always the chance of the land, or a portion of it, becoming more valuable in the event of some economic crop being found which can be cultivated with profit.

The existing land tax, low as it is, is inequitable, since all land privately owned pays the same rate of tax, no matter whether it is of good quality or otherwise, or whether it is easy of access or quite inaccessible. The owner who has gone to the expense of developing his land and putting capital into it, has to pay the same tax as the owner who has done nothing to his land, except to exploit it till it ceases to yield any revenue. The only exception to this rule is the

higher rate of land tax charged in the area served by the British Honduras Railway in the Stann Creek Valley.

Proposals, I understand, are at present before the Government to consider an increase of the land tax. One proposal is to raise the flat rate indiscriminately throughout the Colony, and the other is to raise the flat rate, but at the same time to grant remissions of this, up to the amount of the increase, for any capital improvements which have been or are being made to the property. The latter proposal, it is thought, would have the effect of inducing owners to expend money on capital improvements which would ultimately benefit the country, not only by giving increased employment, but also by increasing the revenue in a manner which would not be felt by anyone, while the former would have the effect of giving an immediate though small increase in revenue estimated at about £5,600 and, to my mind, would merely accentuate the existing inequitableness of the incidence of the land tax, while, at the same time it would discourage any attempts which owners might make to invest capital in their properties.

Both methods are crude, but it must be borne in mind that British Honduras is essentially a forest country. It has a very small population. Very little detailed information is available about the land, most of which has been alienated in large blocks, so that only the boundary survey lines cut through the virgin forest are known at the actual time of the survey. Government has neither the funds nor the personnel to carry out any detailed land reconnaissance, which would enable them to levy a land tax based on the value of the land according to its fertility, accessibility, etc.

The riverine lands are an exception to this general statement. These lands comprise the narrow strip of river alluvium along the natural levees of the rivers and, if agriculture is to be developed, it is these lands which in the majority of cases must receive first attention. As has already been pointed out, it is the general rule that the higher one goes up these rivers the more these river-side lands improve, not only in soil texture but in their extent and lessened liability to flood damage. But the higher one goes up these rivers the more difficult is the navigation. Rapids, or as they are called locally, " falls," are likely to be encountered and there are submerged rocks and timber which are a danger to life and to river craft. In the dry weather, navigation is often slow, and in many places boats have to be hauled up stream where the water is shallow. At the present

time Government does what it can with the funds at its disposal to keep the channels of the main rivers cleared of timber, but it has not been able to do more than this and sometimes not even as much. In some cases private interested parties have attempted to make permanent improvements to the channels by blasting out submerged rocks, etc., but this has only been done in the Belize River where there is an extensive dry season trade between Cayo and Belize, and where mechanically driven motor launches are largely used.

As the lands along these rivers must increase in value if they are made more accessible, and will further increase in value if permanent and profitable agriculture can be developed, it is more in the interest of the owners of such land than in the interest of Government and the general taxpayer, that these waterways should be improved. Government and the country as a whole, can only benefit indirectly by the increased revenue which would naturally follow the increased prosperity of the people. I have suggested therefore, the possibility of levying an acreage cess on such lands, the proceeds of which would be definitely earmarked for the improvement of the waterways of each particular river on which they were levied. This would not only alleviate the existing difficulties of water transport, but at the same time would stimulate the development of the land. I understand that the possibilities of levying such a cess are at present being explored.

VI. EXISTING AGRICULTURE.

Except for the coastal plantations of coconuts, the sugarcane areas of Corosal, in the north, and of Punta Gorda, in the south, and the cultivation carried on by Indians, the agriculture of the country is confined to the river side areas. Looking at a map of the Colony, the only places shown as settlements, which are not on the coast or river banks, are the settlements of Indians.

The Indian agriculture is the oldest in the country, and there are indications that this has deteriorated very considerably since the time of the Maya civilisation. At the present time this is based on fugitive cultivation, but, according to Ower, there are to be found many traces of terracing which point to a more permanent system of farming. Even though it has deteriorated, it is possibly the highest type of agriculture which at the present time exists in the Colony, and is one which, without artificial aids to soil conservation, is

perhaps as suitable to the hilly interior of the country as any other. The highest standard of this indigenous agriculture which I saw was among the Indians of the south, and it is centred round San Antonio and Columbia, which is adjacent to the ancient city of Lubaantun. The town of San Antonio forms a very striking example of what would happen to this type of forest country, if it were brought under permanent arable farming. This town is situated among low hills, which were at one time covered with high forest. It was founded in 1888, when, under the authority of the then Governor, these people migrated from their old centre of San Antonio Veijo. Although the houses in this town are fairly scattered, all forest vegetation has been destroyed within the precincts, and as a result soil denudation has been so complete that the town has the appearance of being built on the rock. One can quite realise that similar soil denudation would have taken place if the hill slopes in the neighbourhood had been permanently cleared for agriculture. Instead of this, the " Milpa " system, as it is called, is practised. This means that the forest is felled and, after the fellings have dried, the area is burnt over. The soil is never cultivated, and is undisturbed except for the actual sowing of the seed, when a small hole is made with a pointed stick and the seed dropped in this and covered. Here are sown maize, beans, cowpeas, pumpkins, and occasionally a little tobacco is planted. By the time the maize is ready for harvest, seedling and coppice forest growth has again formed a fairly efficient soil cover, and the land is then rested for some years, when it is again cleared. Of course the farmer prefers, if it is available, virgin bush, as it is easier to clear and burn than the crowded secondary growth, which springs up on all the cleared land one sees in the colony, but against this there is the disadvantage that such virgin land is further away from the village. The Indian, besides growing sufficient food for his own requirements, as a rule keeps pigs, and these are hand-fed with corn. The pig is, so to speak, his money crop, and there is a regular trade in these with pig dealers in Punta Gorda, who export them either to Belize or to neighbouring countries in Central America. I was very much impressed with the quality and condition of these animals compared with that in most other parts of the Tropics. They are usually herded in the forest in the day time and are driven home in the evening, when they are shut up and fed with corn. Many of the Indians, in addition to their " town house " in the village, have a " country house " nearer to their " Milpas," and here they can live in fair comfort. Besides their crops and their pigs they

have their turkeys and fowls, and many of them also have small areas planted up with fruit trees, while a few of them have established quite useful small cocoa plantations, the cocoa from which they sell through stores at Punta Gorda. Around the houses one sees vegetables and herbs cultivated, besides indigo, annatto, fish poison, and fruit. These people are almost entirely dependent on their own resources for their sustenance, and San Antonio shows an increase of 58 per cent. in its population between the 1911 and the 1921 census, a bigger increase than any other place on the mainland. To show further what these Indians of the south are capable of, it may be mentioned it was mainly due to them, by increasing their crop acreage, that the country was fed during the latter part of the war.

The agriculture of the Creole population, which one sees along the banks of many of the rivers, more closely resembles that which one finds in accounts of native agriculture in West Africa. Here, again, it is fugitive cultivation, though the land is kept under crop for a longer period than is the case with the Indians already described. Forest land is cleared in the same way, either virgin land or secondary growth on land which has previously been cleared (known locally as " wamil "). On the river *front* lands, which are at a higher level, maize is planted, being spaced about four to five feet apart. The seed is sown in holes made with a pointed stick, four or five seeds being dropped in a hole. Where the land slopes down to the swamp, behind the natural levee formed by the river bank, rice is frequently sown. This is sown in the same way as maize, except that the spacing is about two feet apart. In among the maize and amongst the rice as well, wherever the drainage is good enough, cocos or colocasias are planted and at suitable intervals plantains also are put in. These lands are thus kept under crop for perhaps five years. The first year giving a grain crop, the second a root crop, and the second and subsequent years a crop of plantains. When the plantains no longer warrant that the weeds should be kept down by cutlassing, the land is allowed to revert to bush again. If the owner of the clearing lives on the holding, one will usually see fruit trees near the homestead, such as oranges, grape fruit, mangos, avocado pears, guavas, etc. No livestock are maintained till one gets well up these rivers to where pastures have in the past been made.

Then there is the agriculture attached to the mahogany camps, which is confined in the main to clearings, where maize is grown for feeding the mahogany steers and the ponies and mules attached to

the camp. Such clearings are frequently maintained as permanent pastures for the camp livestock, or as permanent holdings where mahogany cattle can be bred or where they can be maintained during the off season. Some of these pastures, which belong to companies working mahogany or to large mahogany contractors, are of considerable age. Many of these pastures are started by planting either Guinea grass or Para grass, according to whether the land is well drained or not, but the bulk of them are natural. Occasionally where a mahogany camp is likely to be fairly permanent, root crops as well as plantains are grown.

Though a few cane plants are to be seen on many of the river-side small holdings and even around the dwellings of the Indian population, cane cultivation is now confined to the Toledo settlements in the south and the area around Corosal in the north. In both these areas it is rather a question of planting canes than cultivating canes, for the land is never ploughed preparatory to planting and, beyond weeding, there is no cultivation carried on. The canes are grown as ratoons for many years—sometimes as long as thirty years without replanting—and it is a matter of surprise how long these lands will continue to grow canes, since there is practically no cultivation and no manuring. Many of these cane soils are comparatively shallow, and one would expect them to become exhausted much sooner than they do.

Bananas and to some extent plantains are at the present time the nearest approach to an export plantation crop that exists in the Colony, and there is no doubt that much hard work is expended in order to grow this crop. As an export crop this commenced in about the year 1880, when 9,000 bunches of bananas to the value of £700 were exported to America. The industry still exists, and at one time appears to have been fairly extensive with an export of some 600,000 stems a year, but it is now on very much smaller lines, owing to the prevalence of "Panama disease." Since it is the only crop which can be disposed of for cash, bananas are still being extensively planted, and the abandoned cultivation of this crop has left its trail of "wamil" up most of the rivers of the colony south of the Sibun river. The cultivation as practised is primitive, and consists of clearing, burning, planting and periodically cleaning. As soon as disease makes itself so apparent that there is no likelihood of a crop, the plantation is abandoned and a fresh planting is made elsewhere, usually further up the river. Except in the Stann Creek Valley, which is served by the

British Honduras Railway, practically all this cultivation is absentee farming. The owner lives on the coast and goes up to his plantation in his dorey or canoe to cut his stems in time for the steamer; he then brings these down to the coast and rests until it is time for him to go up the river again the following week. On some of these rivers the journey up, the collecting and the journey down occupies three days at least and considerably more if the river is in flood.

Cocoa has in the past been grown on a plantation scale on at least three estates in the south of the Colony, but these are now either in a derelict condition or wholly abandoned. Besides this, as already mentioned, the Indians in the south have some quite good small areas under this crop.

A type of stock farming has already been referred to in connection with mahogany operations. There are signs now of this being extended to form stock farms for the supply of slaughter animals for the markets of the colony. There is scope for such enterprise since at the present time several thousand head of cattle are imported annually into Belize from Spanish Honduras. Mr. Stewart, at Orange Walk, in the Cayo district, is the pioneer of such enterprise and is at present subdividing his pasture land into paddocks besides clearing fresh land and planting this up with either Para grass or Guinea grass according to the natural drainage of the land.

Agriculture—i.e. the cultivation of the ground—can be said hardly to exist in the Colony. Occasionally one sees a hoe, and during the course of my travels I saw six ploughs in all, none of which were fully employed. Three of these were double-furrow tractor-drawn disc ploughs. One had not been used till the time of my visit, one belonged to the Industrial School in the Stann Creek Valley, and the third had prepared some ten acres of land for planting grape fruit. Of the remaining three ploughs, one had recently been discovered on one of the cane estates in the north and had been patched up for use. It had been lying about for some thirty or forty years. The second was a small American single-furrow plough, which had recently been imported but had never been used, and the third was a small shovel plough which was used to a small extent on a sandy soil for preparing land for vegetable production.

The main agricultural implement, if it can be so called, is the cutlass or machete, which is used for most purposes such as making plant holes, cutting down under-growth, weeding, harvesting, etc.

For harvesting rice a pocket knife is used, and each head is cut off separately. So it can be understood that harvesting a field of rice is a lengthy and costly process.

During the whole of my travels in the Colony, I only saw one place where real and thorough cultivation was being carried on. This was on a market garden up the Belize River, owned by an East Indian, who had come to the colony from Trinidad, where I gather he had worked at one time in the Government station at St. Clair. On his holding the land was carefully laid out in squares around which were drainage channels. The land, which was a heavy loam soil, was well worked to a full fork depth and was wonderfully improved in texture. The owner was growing really first class crops of vegetables, and the land was under permanent cultivation.

Ordinarily it is stated that land after it is cleared of forest growth will not give more than three crops of maize at the most. This can be understood when it is remembered that no cultivation is given, and that these crops are dependent mainly on the forest debris which survives the clearing and burning. It can also be realised that, without any cultivation of the soil, annual crops such as maize would tend to exhaust fairly rapidly the fertility contained in the surface soil, especially on heavy clay soils such as many of these are. It is this lack of tillage which is responsible for much of the fugitive cultivation which one sees ; for in many places, such as the " Cohune Cays " of the north, permanent agriculture is quite a feasible proposition, provided that the land is properly cultivated.

VII. CROPS OF ECONOMIC IMPORTANCE GROWN IN THE COUNTRY.

(a) *Crops Grown under Arable Conditions of Farming.*

As already mentioned, there is no real arable farming in the colony, but at the same time there are several crops which in more developed countries are solely grown under such conditions.

Maize.—The maize which is grown in the colony is the Indian corn, i.e. the corn or cereal which has always been grown by the Indians or natives of the country. There are I understand three main types based on the time which the crop takes to mature from a quick maturing type said to take from six to seven weeks to mature, to one of long duration, which takes from four to four and a half

months. I was only able to see the last of these growing in the field, and it is characterised by the great thickness of the leaves which form the covering to the cob and to the extension of these leaves to cover completely and protect the apex of the cob. Under the climatic conditions of British Honduras the plants are tall-growing and the cobs are usually high up on the plant. Very frequently the plants are coloured a deep purple, which colouring extends to all parts of the plant, even the anthers of the male flowers show this colouring. It is highly probable that if more detailed investigation were made among the Indian cultivators many varieties of this grain would be recognised, and in different parts of the Colony one finds that in some areas a white grain and in others a yellow grain predominates. One point of interest about these varieties is that they are truly tropical varieties, acclimatised to such conditions and, at any rate as far as the crops of the south are concerned, are adapted to very wet conditions. According to the figures available for the Toledo district the rainfall during the normal growing period is nearly 100 inches. It is quite possible that some of these varieties might prove of great value for growing at low elevations in Tropical Africa.

At present this crop is grown under "Milpa" conditions of cultivation, but it is more than likely that good crops could be obtained from suitable agricultural land under permanent cultivation, provided that the land was brought and maintained under proper tillage.

One matter where the Government could assist is in the investigation of feasible methods of drying and storing the grain. This is of great importance for not only is maize the staple food of the Indian population, but it is extensively required as a feed for horses, mules and working steers, as well as for pigs and poultry. The present method of storing the grain is to store it in the cob. These are closely packed in layers in a covered shed and each layer is liberally sprinkled with lime. In spite of this much of the grain is spoiled by weevil, and this is not to be wondered at when one finds that the weevil has already entered the cob while the plants are still standing in the field. As the grain ripens the practice is to bend over the upper part of the plant including the cob, so that the latter hangs downwards. Here it is allowed to ripen up and in this process it is possible that the protecting leaves may open out sufficiently to allow the weevil to enter. From observation it was seen, however, that the weevil actually will eat its way through this protective

covering to the cob. It is suggested that the American method of harvesting is worth a trial. Here the whole plant is cut down before the grain is dead ripe and these are stooked around a rough wooden tripod. These stooks, if sufficiently large, will protect themselves against the weather while the air space made by the tripod will afford sufficient ventilation and will prevent any undue heating. The crop is allowed to mature for several weeks in this manner and, when a spell of fine weather intervenes, the cobs can be removed and stored. It is thought that, by adopting such a method, the protecting leaves round the cob will remain tightly closed and that since the grain is not dead ripe when the crop is cut, weevils will not have succeeded in entering the cobs before the plants are stooked. It is probable also that the percentage of moisture in the grain when it is stored will be considerably less than it would be if the cobs were collected directly from the field and stored. In the wetter parts of the Colony the grain appears to contain an excessive quantity of moisture when it is stored, and this would naturally lead to much more severe weevil attack. The method of storing in large air tight bins and treating the grain so stored with carbon bisulphide is also well worth trying, but some method of predrying might also be found to be necessary.

Cornflour is prepared by the Indians from this grain, much in the same way as is done by the natives of East Africa, except that in British Honduras the grain is soaked in limewater before pounding as this facilitates the removal of the bran.

Cowpeas.—These are sometimes grown as a subsidiary crop to maize, the seed being sown at the base of the maize hills, the stalks of the maize forming a support for the cowpea as this grows and commences to climb.

Beans. (*Phaseolus vulgaris ?*).—These are largely grown both by the Indians as well as by the people of Spanish descent in the north. The common type is a black bean, which enters largely into the diet of these people. This is grown as a cold-weather crop and ripens up in the dry season. On account of its colour there is not likely to be any export demand for this commodity, except possibly in the adjoining countries where people are accustomed to beans of this colour.

Tobacco.—This is also grown by the Indians and by people of Spanish descent, but only on a scale sufficient to supply their domestic requirements, and one occasionally sees it in the neighbourhood of

dwellings as well as in small areas in the clearings made for growing their cereals. I have tried a cheroot made from tobacco grown in the south and it had much the same flavour as the Guatemalan cigar. Very little attention seems to be paid to the crop which is allowed to grow at will and flower and form seed. It is possible that this might prove to be a valuable crop, especially if grown on the black soils of the north, but a considerable amount of experimental cultivation will have to be done in the first instance to ascertain what type of tobacco to grow and what methods of curing should be adopted. Care will also have to be taken to ensure not only a supply of untainted seed but also to prevent the flowering and seeding of plants under trial, unless they are properly protected against cross fertilisation. It may even be found that the local variety is of value. A filler tobacco for cigars of Empire production would be of value and, if wrappers can also be grown, so much the better.

Cassava.—Although cassava is a common crop, seen in what one might describe as kitchen garden cultivation, it is grown on a much more extensive scale by the Caribs of the Stann Creek Valley on the heavy soils near the coast. Whether this will ever become of economic importance has yet to be proved. No information is available either of acreage yields or of the cost of cultivation, and until data are forthcoming no opinion can be formed. From enquiries made, there appear to be only three varieties of this crop known in the Colony and it would be useful, as soon as Agricultural Stations are established, to procure sets of other varieties which are well known in the West Indies. It is quite possible that some of these may prove to be heavier croppers and more profitable than the existing varieties.

Rice.—Rice of excellent quality is grown in British Honduras. Existing methods of growing this are, however, most primitive and there is little hope of extending the cultivation until better and more permanent methods of cultivation are adopted. The crop is generally grown at the back of a riverside clearing, where the high riverine strip runs into swampy soil. The forest, whether it is virgin or secondary, is first felled, and the fellings, when dry, are burnt. The seed is then dibbled in at intervals of about two feet apart. Beyond weeding nothing further is done till the crop commences to ripen, when birds, which frequently play havoc with the crop, have to be scared away. The harvesting is most laborious. Each head of grain is cut separately with a penknife with a short stalk about

six inches in length. These are tied up in small bundles known as " palms " which is as much as can be held in one hand and these " palms " are placed out in the sun to dry. When rice is to be made from the paddy the whole " palm " is placed in a mortar for pounding. Most of the rice is grown for home consumption, and it is very seldom that this comes on to the market, and, even when it does, it sells for a lower price than the imported East Indian rice of poorer quality. Certainly the local rice does not look so attractive as the imported, since there is a large proportion of broken rice in the local sample. The local rice does not appear to be exacting in its water requirements and seems to thrive as well almost when grown as a semi-dry crop as when it is standing in water. There seems to be no reason why this cultivation should not be much more extensive and much more permanent along the swamps at the back of the high riverine strip. If permanent clearings were made the stumps of trees would soon disappear, and if such lands were surrounded by earthen banks it would be possible to have much greater control over the water which reaches the field. It must, under existing conditions, frequently happen that heavy rain will drown out young crops before they have grown sufficiently tall to keep their leaves above flood level, and this must involve a serious loss to the grower, as it means that he has missed the best season. Further, if the rice areas along these stretches of swamp land were continuous, it would probably be possible to arrange for draining the whole strip as well as to hold up water in times of dry weather. To render such development possible however, cultivation of the ground is essential as well as the levelling of the fields. This can be done on a small scale by means of a hoe, but ploughing with the aid of cattle will prove to be much less laborious and to take up much less time. Before cattle power can be used it will also be necessary to have stumps removed. If such work is attempted it may be found an advantage to grow rice seedlings in a nursery and to transplant these out in the field. If the nursery is protected from flood damage the safety of the crop is much more certain, for a transplanted crop will become established in four to five days. Harvesting also is greatly simplified as the crop will ripen simultaneously and can be cut with a sickle in a very short time. The grain can be threshed out merely by beating the head end of the sheaves on a board after which the grain can be spread out on mats to dry in the sun. There is a constant request that Government should assist growers by providing rice hullers, but until the area

is much larger and the cultivation much more concentrated, there is nothing to warrant such action.

Cotton.—Recently considerable local interest has been aroused in the Colony by a favourable brokers' report received on a small hand sample of kidney cotton which had been sent to England. This type of cotton is fairly frequently seen growing in house compounds, and appears similar to that found in Trinidad and British Guiana. It is a perennial cotton, and would be difficult to grow and keep clean in a country where nothing is known about arable farming. Further, though an odd plant in a compound may remain comparatively healthy, it is very doubtful, if cotton were grown as a crop, that this would be the case. The cost of picking would also be heavy, and I do not see any future for cotton as a crop under existing conditions of agricultural development in British Honduras. The ordinary Upland type of cotton is commonly found around dwelling houses in the north of the Colony, and appears to be quite at home there. The plant grows as a perennial, and grown in this way appears to remain quite healthy. There is no doubt that cotton of this type could be grown in the Colony, but similarly with the above, agriculture would have to improve very much before it could be considered.

Sesamum.—One frequently sees small areas of this crop raised either in house compounds or in temporary clearings by the Creole population. Often also, one sees bundles of the harvested plants tied up and stored in the house just as may be seen in East Africa. I gather that the seed is used for making sweetmeats, as is done in Turkey, and that its value as an oil seed is unknown. The local value of the seed is very much above its export value, and it is doubtful whether this will ever become of importance, as it is a costly and troublesome crop to harvest.

Sugarcane.—This crop is still grown to a certain extent on a small plantation scale both in the Toledo and the Corosal districts. The cultivation, if it can be described as such, is on the extensive rather than the intensive scale, and it is highly probable that the crop would be much more profitable if more attention were paid to actual tillage and after cultivation rather than to the area under cane. At the present time the main items of expense, outside the factory, consist of weeding, cutting and carting, and it is evident that if the acreage could be reduced by half and the acre yield doubled, the cost of production would be very much reduced. Further than this, if efficient cultivation were given to the fields and attention were paid

to improving the mechanical condition of the soil, the canes would grow and ripen much more evenly. In the north, where the rainfall is much less than in the south, this is of special importance. At the present time whenever there is a tendency to drought, the growth stands still and fresh shoots are made when moist soil conditions again occur. This must mean not only a low sugar content, but a high percentage of glucose. Good preparatory cultivation and a system of earthing up the canes might, therefore, make a considerable difference in the yields and in the cost of production.

The variety of cane, which is chiefly met with, has been grown in the Colony for a very long time. It has been described by Morris as the Bourbon cane, but whether it is this, or whether it is descended from one of the thick light-coloured canes of South India, it is difficult to say. As far as one could see, the variety is still quite vigorous, and it has evidently adapted itself to local conditions. The cane in the south is apparently the same variety as that in the north, but growers in the north informed me that crops grown with sets procured from the south do not do well with them, so, if they are the same variety, it is evident that the plant has adapted itself to suit local conditions. Further, both in the south as well as in the north, other seedling canes have from time to time been obtained from the West Indies and from British Guiana, but none of these have ever taken a hold. I understand that the main objection to all that have been tried is that they have not got the staying powers of the local cane when grown continuously as a ratoon crop, and even when grown as a plant crop they are said to deteriorate when the variety has been in the country for some time.

Considering the scanty cultivation which the cane crop gets in British Honduras, the crop appeared to be remarkably healthy. The only serious pest which I came across was frog-hopper damage, which in some seasons causes serious loss. This only occurs in the south and is, as has recently been shown in Trinidad, probably associated with soil acidity.

For the manufacture of sugar each estate has its own small factory. On more than one occasion I was asked my opinion as to the value of a central factory to operate the canes from several estates. I could not see that the present condition of the industry would warrant such an undertaking. Extensive cultivation such as exists at present is bad enough when canes have to be led to a local factory, but conditions would be very much worse if such crops had to be led to a

central factory. Much more intensive cultivation is necessary before anything in the nature of centralising the manufacture can be contemplated. The local producer complains that he is unable to obtain an adequate market for his sugar, and suggests as the reason the increasing demand there is in the Colony for imported refined sugar. The imports of the latter are certainly large, when the quantity of locally produced sugar is also taken into consideration, and amounted in 1927 to 28 lb. per head of population. Between £14,000 and £15,000 left the Colony in that year to pay for sugar. Morris states that, in the year 1881, 1,902 tons of sugar were exported from the Colony valued at £37,836.

In the north of the Colony the manufacture of rum is of some importance, and approximately 50,000 gallons of proof spirit are made in the course of a year. In the cane areas of the south most of the molasses are utilised for pig raising and as feed for livestock.

(b) *Crops Grown under Permanent or Semi-permanent Conditions.*

Bananas.—Though British Honduras claims to be the first place which attempted the export of bananas on a commercial scale to temperate countries, the industry has had a very chequered career, and this, if nothing else, makes one cautious about recommending any crop to be grown until it has been properly tested out on agricultural stations. Writing in 1883, Morris says :—" There are some thousands of acres of splendid land suitable for banana cultivation in this Colony, which offer every inducement to experienced planters to settle down and reap the returns which must inevitably attend the judicious and careful culture of this fruit." It certainly looked as if this statement were true at one time and so promising were the prospects of this industry that the Stann Creek Railway was built to deal with the traffic which was expected from this crop. For a time all went well and the export rose to some 600,000 stems a year, but it is evident now that the crop was dependent on the surface fertility of the soil, due to accumulations of forest debris on the land, and that when this was once depleted the plants succumbed to " Panama disease," this disease being particularly virulent on account of the soil acidity and the impervious nature of the subsoil. Not only in the Stann Creek Valley, but up the Sittee and Monkey rivers, there were extensive areas of bananas grown along the riverine lands, and even now the cultivation is being extended further and further up these rivers as the plantations lower down succumb to

the disease. I was very much impressed with a small plantation which I saw on the Monkey river, quite near the coast at the head of the delta region of the river. Here the soil was a free-working sandy loam, quite distinct from the usual heavy laterised clay, which is generally associated with the soils near the mouths of these rivers. This small plantation had been growing bananas for some twenty years and was still free from disease, though lands in the neighbourhood had long ago been abandoned on account of "Panama disease." At Bomba, on the Northern River, bananas have also been grown for many years without any sign of disease, but here the soils are sweet, being a Cohune ridge black loam resting on limestone and marl. The soils suitable for bananas in this area are limited, however, and there can never be any great extension of the crop here. It seems indicated, therefore, that the incidence of "Panama disease" is closely connected with soil conditions, especially those associated with soil acidity and drainage.

Plantains.—Although this is a crop closely allied to bananas, there appears to be much more prospect of developing its cultivation, as it does not seem to be nearly so exacting in regard to soil conditions, and is able to thrive where the banana would succumb to disease. Still even here more cultivation appears to be necessary than is usually given. The manager of the United Fruit Company at Belize informed me that he received unsatisfactory reports on plantains shipped from the Colony, and these stated that they compared unfavourably with fruit shipped from the Central American Republics. The fruits were not so well developed, nor did they travel or keep so well. If the soil were dug over and the mechanical condition improved, it is probable that these defects would be removed. If improved cultivation of the plantains became the customary method, it would pave the way for better cultivation of the banana, if and when varieties are produced which can comply with the conditions for transport and also prove resistant to the "Panama disease."

Grape Fruit.—There is no doubt that the climate of the colony is admirably adapted for the production of Citrus fruits, and on the river alluvial soils which have adequate drainage, grape fruit of very fine quality can be grown. In most settlements in the Colony this fruit is to be seen, but unfortunately most of the trees are seedling trees and there is no uniformity in the quality of the fruit produced. The quality of the fruit which is grown on the black loam of the Cohune ridges of the limestone and marl country is also excellent.

There are two orchards of grafted trees, consisting of the Marsh and the Duncan varieties, in the Stann Creek Valley, both of which are on good river loam soils. These two orchards consist of about 20 acres in all, and last year the quantity of fruit which was exported from this area amounted to over 3,000 cases. The success of this venture has had the effect of enhancing the value of land in the Stann Creek Valley, but as the major part of this valley is not a river alluvial loam but a stiff laterised clay, the opportunity for developing this industry here is not as bright as was at one time thought. Anyone attempting to develop grape fruit orchards here should make a careful examination of the soil to see that drainage conditions are good enough to warrant a start. The Stann Creek Valley is not, however, in my opinion, the only part of the colony where grape fruit can be successfully grown. On the upper reaches of most of the rivers south of Belize, as well as of the Belize River itself, good river alluvial soils are to be found, which in my opinion, could be developed for grape fruit, while judging by the quality of the fruit now grown and the condition of the trees, the black Cohune ridge soils of the limestone areas are capable of producing first-class fruit. This crop seems to be admirably adapted to the needs of the country. A small area of land is capable of giving quite a good living. The sales last year at Covent Garden gave an average net return of 19*s*. a case ; and, averaging a case at 68 fruit, the crop from the Industrial School's small orchard of nominally 16 acres (it is considerably less than this if seedlings and other miscellaneous trees are excluded), 2,003 cases gives a return of £1,903, from which the costs of cultivation, packing and freight have to be deducted. The charges for packing, local transport and ocean freight amount to approximately one-third of this amount, so that the orchard brings in a return of about £1,250, which has to bear the costs of actual fruit production. These may seem rather fanciful figures, but it must be borne in mind that the quality of British Honduras grape fruit is as good as, if not better than, any that comes to the English market, and therefore the prices paid at Covent Garden are well above the average. There is no doubt that when the production increases prices are bound to drop, but even so the profits from this crop are likely to be ample to make it most remunerative. With only some 20 acres of grafted trees in the country, it can be understood that the crop is still in the experimental stage, and a much larger acreage is necessary to put it on a firm financial basis. Progress for the next few years will be slow, as, on the advice of Professor Clark Powell, the importation of

graft trees from outside has been stopped on account of the danger of introducing pests. In the meantime, the Industrial School in the Stann Creek Valley has developed the work of producing grafted trees, and these are being produced in gratifying quantities. Already the acreage of grape fruit is steadily increasing, though it will be three or four years yet before these new orchards will begin to yield on a commercial scale.

Loose-skinned Oranges.—This appears to be a crop which should have a future before it. Mr. Bowman, in the Stann Creek Valley, one of the pioneers of the *grafted* grape fruit industry, has now a considerable number of trees of the tangerine orange in bearing, and it seems likely that this crop would fill in a blank in the present supplies reaching this country. I saw the crop in September, and the fruits were then just beginning to turn colour. If they could be shipped at this time of the year, the supplies would come in at the close of the South African crop and before the Mediterranean fruit reached the market.

Cacao.—This, to my mind, is the ideal permanent crop for British Honduras, and it is admirably adapted to the present conditions of agriculture in the Colony. It is a crop which is not so particular as to soil conditions as are many other crops, and cacao would probably thrive on much of the area where bananas have succumbed to "Panama disease." The establishment of cacao fits in very well with the local Creole agriculture, and the cost of establishing a crop would be very small. When once established, the crop would require very little expenditure, since the shade cover produced by the cacao tree itself, along with that formed by the actual shade crop, is amply sufficient to keep down weed growth. Experience, gained in other parts of the world, has shown that it is peculiarly the plantation crop of peoples of African descent and is well adapted to other primitive types of agriculture. A clearing made for growing maize, cocos and plantains or bananas brings in a monetary return from the first year, while the plantains or bananas will provide the necessary shade for the young cacao and can, when the latter is grown, be removed. The main expense after that will be the harvesting, fermenting and drying of the beans. A further advantage is that the produce is not immediately perishable, as is the case with the existing crop grown, namely, bananas, the marketing of which wastes an enormous amount of the time of the producer.

Cacao is indigenous to the country and plants of the Criollo type grow wild in the better types of forest, so there is no question as to the climate not suiting the crop, though in the north the rainfall may prove to be insufficient. It may be said that earlier efforts to grow cacao in the colony have not been attended with success, but it must be remembered that such were large-scale enterprises, entailing the employment of hired labour and heavy overhead charges. The industry was accustomed to much higher prices for cacao than rule at the present time and the necessity for economic and efficient management was not so insistent as it would be under present conditions. Cacao cultivation, even on a large scale, was, I understand, commercially successful until the increased supplied from West Africa lowered prices generally. Cacao grown by the small grower has not to carry overhead charges, and is not dependent on hired labour. Grown in this method there is, I consider, every chance of a profitable industry being built up. I was able to see cacao growing under various conditions in the Colony, and what I saw confirms my opinion that this crop offers great opportunities of becoming one of the most important agricultural products of the country. I was able to see an estate up the Sittee River, which is in a very neglected state, but what impressed me more than anything was the healthy and vigorous condition of the cacao trees under the scanty attention which they received. In and adjoining the Indian reserve in the Toledo district, I saw several very promising peasant holdings of cacao. From one of these small areas the owner informed me that last year he had sold 2,000 lb. of cacao at 16 cents a pound locally, which speaks well for the quality of the cacao produced, and I understand that enquiries are now being made in the Colony to purchase this commodity in much larger quantities. A sample grown by one of these Indians was obtained and a report on this is attached as an appendix by the Imperial Institute. One feature noticed in connection with this development among the Indians of the south, was the remarkable uniformity of the type of cacao grown.

Arabian Coffee.—This plant seems to thrive remarkably well on lands which have efficient drainage, and one sees it as a back-yard cultivation in all parts of the Colony, from the moist coastal districts in the south to the driest parts of the Colony in the north and west. At one time there was a coffee plantation near Cayo, which Morris visited in 1882 shortly after it was started, and he was impressed with the possibilities of this crop in this area. Even at that time

he contemplated the importation of East Indian labour to put the crop on a sound basis and to extend its cultivation to fresh areas. The plantation, I was informed, has now been abandoned, and this is not surprising, as practically all labour in this district is employed in collecting chicle, at much higher rates of wages than could be obtained from a plantation industry such as this. I do not see much prospect of developing this coffee industry under present conditions of labour supply, except perhaps in the north. The harvesting is too laborious and protracted to make it worth while. It is, however, possible for the small settler to make a profit from small areas, which he could work with such labour as his family would supply, and for some time there should be a ready local market for the produce. The imports of coffee into the Colony amounted in value to over £5,500 in 1927. I have tasted coffee made from locally grown beans and it is infinitely superior to much of that now imported.

Liberian Coffee.—As long ago as 1882, Morris drew attention to the possibilities of this species of coffee as a plantation crop for this country, but nothing has really been done to establish it as a crop. There are a few neglected trees in the Botanic Gardens, and I saw a few remarkably vigorous trees in the Stann Creek Valley, which were bearing excellent crops. This plant seems to adapt itself well to *acid* soil conditions, and there is probably a large scope for its extended cultivation. It is a crop which requires much less labour than the Arabian coffee, as the tree will hold its fruit when ripe for a long period, and this would give a limited labour supply ample opportunity for picking the crop.

The lands behind Belize, through which the new Burdon Canal is being cut, reminded me very much of the soils in the N.W. district of British Guiana, except that these appear even better and richer. There is a possibility that these may be developed in the same way as is being done with similar land in British Guiana. It is only a possibility, however, and should be investigated before anything else is done. The lands in question are very little above sea level, and, even if drained and enclosed with embankments, it is not certain whether salt water can be kept out. If this is not possible then there is little hope of growing this class of coffee here. There is however, ample scope along most of the rivers in the Colony for such a crop, and it is probable that it will succeed on the more heavy types of soil nearer the coast.

Coconuts.—This can be said to be the only plantation crop which is really established in British Honduras. This is the third most important export from the Colony, and coconut products to the value of £46,000 were exported in 1927. It is a bad third, however, and is only about one-sixth in value to chicle and one-tenth in value to mahogany. It is, however, an expanding export and, compared with the average annual export for the previous four years, this in 1927 showed an increase of 12 per cent., in the case of nuts, and 78 per cent., in the case of copra. Nuts, which are exported as such, are all graded and selected for size and soundness. The coconut areas are mainly those along the coast and on the cays, but there is a certain area of plantations on the coastal lands at and near the mouths of all the southern rivers, where settlement has taken place. The coastal trees are usually fairly healthy, as long as they are facing the sea, but where they face the lagoons behind, where there is little drainage, the growth is usually poor. The areas in the north of the Colony appear to give the best sized nuts, as far as the mainland is concerned, and the trees here are mostly grown on coastal land of the "high forest" type. The crops in the north are assisted by the low rainfall, as the land is on the heavy side, and if the rainfall were heavier the trees would feel the lack of drainage. Near the river mouths the soils are usually heavy and ill-drained, and, though the trees may bear heavily in their early years, coconuts cannot be looked upon as a permanent crop. It is very noticeable travelling up the Belize river that there are hardly any old trees to be seen as far up as Boom. Above here, where the banks are higher and the soils are more open in texture, old trees are quite common. The trees on all these heavy lands are very liable to disease, which appears to be what has been described in other parts of the West Indies as "Red Ring" disease. The coconut of British Honduras is of a different type to that found in the West Indian Islands. It is usually green in colour before it dries out, and has a longish fruit containing a round nut.

Henniquin.—This appears to be indigenous to the country, and on more than one occasion I was asked whether it would not be possible to establish this crop here. I can see no future for this crop in British Honduras. In the first place it would be difficult to get large compact areas of good land for growing the crop in such a way as it could be handled efficiently, and in the second place labour is much too scarce and expensive to allow of any profit from such cultivation.

VIII. ANIMAL HUSBANDRY.

Cattle and dairying.—Mention has already been made of the pasture lands along the upper reaches of the Belize river. Originally formed for the purpose of grazing mahogany steers, and for breeding these, as well as breeding horses and mules, extensive pasture lands have been made from areas of high forest along the river banks. With the introduction of mechanical traction the demand for mahogany steers is now on the decline, but there is scope for animal husbandry, not only for the meat supply of the Colony, but also for the supply of dairy produce. As regards beef, I understand that some 6,000 head of cattle are imported annually from the Republic of Honduras to supply the Belize market, and there is no reason why the whole of this number should not be produced within the Colony itself.

The natural pastures which spring up on these clearings, when they are not allowed to revert to secondary bush, consist almost entirely of three local grasses, viz. *Paspalum minus* Fourn., *Paspalum conjugatum* Berg. and *Axonopus compressus* Beauv. These grasses make an excellent turf and are well grazed by cattle. In addition to these natural pastures, there are also artificial pastures consisting of Guinea grass, on the better drained lands, and Para grass on the more swampy soils.

The type of animal raised is usually of the style of the Spanish cattle common in Central America and the West Indies, though of recent years there has been a certain admixture of Zebu blood by the importation of breeding bulls from Jamaica. It is curious that the industry of the country, in making a demand for a strong draught type, seems to have altered these animals. There has never been any thought of utilising the female stock for dairy purposes and the breed seems to have lost any milking qualities which it may have possessed. There is a marked difference in the appearance of the cows here to what one sees in the Spanish countries of Central America, where there is a local demand for milk and milk products, and where some very useful dairy cattle and dairy farms are to be seen. In British Honduras all milk products are imported and fresh milk is a rarity. The value of these imports amounted in 1927 to £52,250.

There seems to be a certain amount of deterioration among the breeding stock one finds on these riverside pastures. There is a tendency to excessive development of horn and to a lack of bone,

which one usually associates with animals grown and kept in areas where the soil is deficient in lime and phosphates. Among working steers this is not so noticeable, since while working in the forests, which are mainly on the limestone formation, the animals are not grazed, but are fed on the leaves and fruit of the bread-nut tree (*Brosimum alicastrum* Swartz.), together with a hard ration of maize. It is probable that young working steers can thus make up for much of the deficiency in their diet as calves when they are broken in to work.

Sheep.—Sheep are not common, and I understand that their meat is not appreciated by the people of the country, but I consider that there is room for sheep on these pastures, if only to keep down other growth than natural grasses. In place of the existing breed of wool-bearing sheep I would suggest that the hairy sheep of India would be much more suitable. They fatten up much better and are much more suitable to a country such as this which has a fairly heavy tropical rainfall.

Pigs.—Much can be done to improve the local breed of pigs by the importation of boars for early maturity. At some time recently Berkshire boars have been imported, and one sees the results of such importations in several parts of the country where their early maturing qualities are greatly appreciated. In view of the fact that the Indians in the south have developed quite an industry in pigs, and not only understand their management, but do look after and feed their animals properly, the stationing of a few stud boars here might give a decided impetus to this industry. The present lot of pigs in the country are of very mixed origin. The black colour predominates and is probably most suitable to a tropical country, but one sees pigs of all colours and shapes. One peculiarity about the pig, which I have not seen elsewhere, is that a large proportion of them have tassels under the jaw, such as one frequently sees on goats and tropical breeds of sheep. The country consumes a large quantity of pork, as this is the standard meat ration for the mahogany camps; in addition to this 455,000 lbs. of lard and lard substitutes were imported into the country in 1927.

Poultry.—This is an industry capable of large expansion, even if only to supply the internal needs of the Colony. It is an industry moreover peculiarly suitable to the small settler. Prices for eggs and poultry are astonishingly high in Belize, and would probably average higher than prices in Great Britain. Not only this but such

produce is at times extremely scarce, and it is with the greatest difficulty sometimes that eggs can be purchased, either in Belize itself or even in the country districts. So scarce are eggs that *preserved eggs* are imported into the Colony from the United States. Yet the poultry which one sees in the country districts compare very favourably with those one usually sees in the tropics, both in size and in general healthy appearance. The turkey, which is stated to be the domestic bird of the Maya Indians, also appears to thrive remarkably well and one sees these at nearly every homestead in the country districts. With a little organisation and co-operative marketing this industry could, I consider, be easily developed.

IX. OTHER NATURAL RESOURCES OF THE COUNTRY WHICH ARE NOT UTILISED AT THE PRESENT TIME.

Cohune nuts.—These are the fruit of the cohune palm *Attalea Cohune* Mart. These palms are characteristic of the better drained deep soils of the Colony ; on such land they occur throughout the Colony irrespective of the character of the subsoil or of the climate. It is on land where the cohune palm is found that the greater part of the agricultural exploitation of the forests has taken place. In the forests, the cohune palm is generally in a suppressed state, and a very small proportion of the palms seem to be able to form a stem to get their heads above the forest canopy. It is only when the palm can do this that it will bear fruit. Thus in natural forest the number of fruiting palms is very limited. If however the land is cleared of high forest many of them can then develop, and in the pasture lands of the Colony, the cohune attains excellent growth and development and fruits freely. If therefore pastoral farming can be encouraged there is the possibility of a subsidiary industry, if methods and machinery can be found for dealing with these fruits. The nut of the cohune has a very hard shell, and enclosed within this shell are are from one to three kernels. The kernels represent about 10 per cent., of the weight of the fruit, and furnish a valuable oil seed, as the kernel contains from 68–70 per cent. of oil. The oil is similar to that obtained from copra and the kernel of the West African Oil palm. If the fruit is quite ripe when harvested, the percentage of free fatty acid is said to be very low. Morris, writing in 1882, states that " the oil is said to be superior to that of the coconut and to burn twice as long." The oil is used to a certain extent locally, the nuts being broken between stones and the kernels, after pounding, being

boiled in water, when the oil is skimmed off as it floats to the surface. Up to the present no satisfactory and economic machine has been placed on the market, which can deal with the problem of cracking the nuts and separating the kernels from the shell. Large machines have been made, suitable for a central factory, which are said to be able to deal with the nut, but this does not overcome the difficulty of transport. It is the cost of collecting the nuts and taking them to a central factory, which has caused such enterprises as have been tried in the past to fail. What seems to be required is a portable machine drawn and worked by a tractor engine which can be moved from place to place, so as to be within easy reach of the fruiting trees, and which can crack the nuts and sort the kernels on the spot. It is the kernels which are of the greatest value and these represent only some 10 per cent., of the weight of the fruit, so that, if a machine of this type were forthcoming, some 90 per cent of the cost of transport would be saved. I suggest that the Empire Marketing Board might consider the feasibility of importing a few tons of ripe nuts into this country, and offer an award for the best type of machine on these lines which can be invented.

If any steps such as are suggested were adopted, a number of data connected with the trees should be collected. Very little seems to be known about the rate of growth and the fruiting properties of the tree. How many bunches the tree forms in a given time, at what season of the year the tree flowers, or whether it can flower all the year round, whether there is variation in the number or proportion of male and female inflorescences, and if so, what is the probable cause of such variation, the length of time which it takes for the bunch to ripen from the time of flowering. How long it takes for the tree to come into bearing, either from seed, or from the suppressed condition of growth which occurs in the high forest. Other points of interest which might be examined are the variation in the size of the nut and of the bunch, and how far the better type of nuts, i.e., those with a single kernel, is hereditary and how far it is due to environment. If economic methods of dealing with this product can be devised there is no doubt that the cohune palm will have a considerable influence on the future progress and prosperity of the country. An American gentleman whom I met in the Colony, and who was interesting himself in the problem of exploiting this palm, informed me that the interests which he represented had already obtained the royalty rights over a machine for cracking these nuts.

Silk Grass or Pita Fibre.—This is found occasionally growing wild in the high forest and yields a valuable fibre. Whether there are sufficient plants in the forest for the profitable exploitation of this fibre has yet to be investigated.

Heliconia sp.—A giant *Heliconia*, growing to a height of 12 to 15 feet, at present unidentified, is common along the banks of the Columbia branch of the Rio Grande. This yields a fibre from the younger leaf sheaths of the pseudostem very similar to Manila hemp. This plant may prove worthy of further investigation. A preliminary report by the Imperial Institute on a small hand sample which I extracted from a single stem is as follows :—

Description.

The sample consisted of fibre about 4 feet in length, generally well-cleaned and prepared, though not very lustrous. The strands were of about the same thickness as the finer or better grades of Manila hemp. The strength was somewhat variable, but on the whole fairly good, though inferior to that of good samples of Manila hemp of the same thickness.

Results of Examination.

The sample was insufficient for chemical examination.

On microscopical examination the ultimate fibres were seen to possess a very well-defined lumen which varied considerably in diameter, being sometimes much wider and at other times narrower than the fibre walls. The ends of the fibres were fairly sharply pointed, the lumen generally extending almost to the tips. The ultimate fibres had the following dimensions :—

	Length. mm.	*Diameter.* mm.
Maximum	9	0·0279
Minimum	3	0·0127
Average	5	0·0178

The microscopic appearance of the ultimate fibres was not altogether unlike that of the fibres of *Musa* spp., but the dimensions quoted above show that they were slightly shorter and narrower than those of *Musa textilis* and longer and narrower than those of banana fibre (*M. sapientum*).

The fibre, if offered in commercial quantities, would find a market for cordage manufacture, but before a definite value could be assigned to it a larger sample would be required for examination and submission to the trade.

There are several species of *Heliconia* found growing in profusion in different parts of the Colony, and it might be worth while having these investigated at the Imperial Institute as to their suitability for paper making.

Balsa or Raft Woods.—(Polak, *Ochroma bicolor* Rowlee., Quam, *Schizolobium parahybum* Blake., White Moho, *Belotia Campbellii* Sprague., and Yellow Moho, *Heliocarpus Donnell-Smithii* Rose.) These are all very light woods, whose properties, except the last, have been examined by the Imperial Institute for their timber qualities. Further examination as to their value as insulating material appears to be advisable, especially now that the use of food preservatives has been so restricted by legislation, and the demand for refrigerators has increased. I understand that there is already an export of *Ochroma bicolor* from Central America to the U.S.A. for this purpose, and as the tree is common in "Wamil," is very fast growing, and can be utilised as temporary shade, the possibilities of a remunerative market should not be overlooked.

X. TRANSPORT.

The question of better transport facilities is occupying a good deal of attention at the present time, and it would be as well as a preliminary to this question to consider what products have to be conveyed, what method of conveyance is suitable, and what prospects there are in the future for expanding these industries.

Taking the main exports of the colony for the year 1927 as a basis of present traffic, the following are the chief items :—

Mahogany and cedar ..	about 33,150 tons.
Chicle	1,354 tons.
Coconut products ..	about 7,500 tons.
Bananas	about 3,000 tons.

Mahogany is at present conveyed to Belize for shipment by water. The logs are hauled from the forest either by bullocks or by tractors, usually to the banks of a river, or alternatively to the rail head of a logging railway, from whence they are taken to the riverside. From

here they are allowed to float down the river, when the latter is in flood, till a boom in the navigable part of the river is reached, and here the logs are collected, sorted and made up into rafts which are then towed down to the coast. Nearly every river in the Colony makes its contribution to the total quantity. As far as the south of the Colony is concerned, where all the rivers flow eastwards, there is no alternative method possible, but where the rivers flow northwards, i.e. into the Bay of Corosal, from where the rafts have to be towed the whole way down the coast to Belize, since there is no depth of water for any nearer loading, it is felt that a railway, which would connect the New River with the Belize River would not only enable timber to be brought down all the year round, but would probably be cheaper than the present method of water transport, involving as it does a very long haulage. Coupled with this is the fact that the Belize Export and Produce Company have already built a substantial logging railway from Sierra d'Agua to Hillbank, a distance of about 13 miles, and there is a probability that this line could be extended to the Guatamalan frontier, thus tapping new mahogany areas, at present so far distant from transport facilities that they cannot be worked at a profit. If such a railway were built to the frontier it would further open up mahogany forests in Guatamala, especially if the authorities there were to come to some agreement to extend the railway into that republic. What this Guatamala trade would be worth would necessarily be a matter of negotiation.

Cedar is much in the same category as mahogany, except that it is more especially a tree of the limestone areas, and therefore is likely to be more important along the line of a proposed railway than in the south.

Other Timbers.—Very little can be said of other timbers at the present time. A market has to be created for these and a considerable amount of investigation and research is necessary before profitable markets can be assured.

Timber traffic in general is not suited to other modes of transport. The use of permanent roads for this traffic is out of the question, unless very heavy initial expenditure is incurred in making these roads, and unless the country is prepared for very heavy recurring expenditure on the upkeep of roads. Any ordinary type of road, which in other countries might be considered sufficient, could never stand up to heavy timber traffic here.

Chicle.—This is at present largely collected at Cayo, but also to some extent at Corosal, and from these places it is conveyed by water to Belize. The total quantity, however, is small in both bulk and weight and amounts to only some 1,300 tons. This is not really of sufficient importance to be taken into account when considering questions of transport.

Coconuts.—These are mainly grown on the coast and on the cays, and the present methods of water transport are likely to continue to be the cheapest and most convenient.

Bananas and Plantains.—These are chiefly grown up the Stann Creek and the Sittee and Monkey rivers ; they are brought down to the coast and loaded on to steamers, which call regularly and lie out to pick up the cargo. In the Stann Creek Valley these are brought down by rail, and on the other two rivers by dorey, no other means of transport are feasible. The cultivation on the Northern River shows that these do well on the black loams overlying the limestone formation, and it is possible that the better class lands, in the neighbourhood of Hillbank, might grow bananas which would be free from " Panama disease," but such a development would be dependent on the existence of a railway and on land being made available on suitable terms to settlers.

It will thus be seen that as far as existing exports are concerned there is nothing to warrant any other methods of transport than those which already exist, except in the case of timbers, of which mahogany is the most important.

As far as imports are concerned, a study of the distribution of the existing population as given by the last census returns, shows how small the proportion of such must be to any particular locality—not sufficient at any rate to warrant any immediate action in spending large capital sums on the improvement of transport facilities. A summary is given below of the last census figures of population.

District.	*Urban.*	*Rural.*	*Total.*
Belize . . .	12,661	4,737	17,398
Corosal . . .	2,079	4,677	6,756
Orange Walk . .	1,175	4,432	5,607
Cayo . . .	2,234	3,130	5,464
Stann Creek . .	2,925	1,925	4,850
Toledo . . .	1,350	3,892	5,242
Total . .	22,524	22,793	45,317

With the exception of the Caya and Toledo districts, all the population is confined either to riverside or coastal settlements. These figures show that there is no concentration of rural population, but that the population is fairly well scattered over the Colony. In no district are there sufficient inhabitants to warrant heavy expenditure on improving transport conditions, until it can be shown that production is sufficient and is suffering from want of better facilities. As regards the urban population, 19,015 are located in coastal towns, while of the rest, the people of Orange Walk have a regular steamer service to Belize. There remains, therefore, only the town of Cayo, which has any serious difficulty of getting to the coast, and this is mainly in the dry season. The only matter for serious consideration about these figures of population is the preponderating number of people resident in Belize. This, however, would not be altered by heavy expenditure on improving transport facilities; for even if these people were to move out of the town, they would only drift back again, unless they can be shown how to earn their living on the land, and this can only be done by the results of the work of the Agricultural Officer. It is time enough to think about such expenditure when the Agricultural Officer has definitely shown what crops can be grown with profit in different parts of the Colony, and what areas of crop are necessary in order to give an adequate livelihood.

Railways.—The question of building a railway from Belize, or from a navigable point on the Belize river, to the Guatamalan frontier was much in evidence at the time of my visit, and though no route has ever really been surveyed, I understand that the one which is thought to be most suitable would be from Bakers on the Belize River to Hillbank, a distance of some 25 miles. From there on, utilising the existing line from Hillbank to Sierra d'Auga, to the frontier following the line of least resistance, as far as hilly country is concerned, which would probably be in a north-westerly direction. From Bakers to Hillbank the cost would not be great, since the route would be over pine ridge, which would give a good natural ballast, besides being almost level. Being pine ridge, however, the country traversed in this section would never be able to produce any revenue unless the pine forests were strictly reserved and protected, and it would be a long time before they would be productive, so badly have they been damaged in the past by fire, etc. From Hillbank to the frontier there are some of the best remaining mahogany forests in the Colony. These owe their value to the fact that they have not been

heavily exploited in the past, owing to their inaccessibility. With the advent of tractor haulage and logging railways this inaccessibility can be to a great extent overcome, especially if the proposed main line of railway becomes an actual fact. Unless, however, there is some guarantee that these forests are going to be properly conserved and not exploited, as have all other areas of accessible forest, it would be very unwise for the Government of the Colony to have anything to do with the financing or guaranteeing of such a line. Even as regards the traffic from across the frontier, there would be the same danger of the supplies of traffic disappearing as the timber was cut out. It must be remembered that mahogany grows in a mixed forest and that first-class forest does not average more than two trees of fellable size per acre.

I have been asked whether it would not be possible to develop the area through which a railway would pass, by growing agricultural produce and thus create traffic for the future. It is difficult to make any definite statement. I certainly think that there is land between Hillbank and the frontier, which is capable of considerable agricultural development, but there are so many other considerations to take into account, such as dearth of population, especially population which are agriculturally inclined, high cost of wages, and lack of knowledge as to the economic possibilities of different crops, and possibly difficulties in regard to water supply, that it is not possible to say anything definite at the present time. Further, all this land is privately owned, and unless it is known on what terms people can take up land and whether they are to be given security of tenure, the future development is merely a matter of conjecture.

Roads.—As one would expect in a country which is mainly forest, which is so thinly populated, and where the existing population resides either on the coast or along the banks of the rivers, roads are conspicuous by their absence. Near the towns of Corosal and of Cayo, where there is ample metal available and where there are facilities for natural drainage, there are a few miles of fair roads, and the same is true of the road which connects the Toledo settlement in the south with Punta Gorda. But beyond this there are no roads in the colony except those within the towns themselves. Recently a road from Belize to Corosal was sanctioned by the Legislative Council, and work on this was commenced. Subsequently this was held in abeyance through lack of funds, and I was asked my opinion as to whether I thought that such expenditure was justifiable. Considering

that the proposed line of this road traversed country which was composed almost entirely of pine ridge, from Bakers on the Belize River to Orange Walk on the New River—land, which is of very small agricultural value—I was compelled to state that I thought that, considering the present state of the finances of the country, any money available could be spent with much greater advantage in other ways, more especially in improving the inland waterways of the Colony. This would do much to assist settlers on the more valuable agricultural lands. If such a road had opened up good agricultural land and had there been a prospect of developing a prosperous agriculture by this means, my answer might have been different, and it would have had to depend on an engineering report estimating the cost of maintenance as well as the cost of construction.

In undeveloped countries such as British Honduras, the main object of a road is to convey produce from the centres of production to the centres of commerce and to open up new areas for the development of production. In many undeveloped countries merely cutting down the bush, stumping, together with a certain amount of cambering and drainage is all that is required. This is largely due to the fact that the produce which is to be conveyed can be transported in the dry months of the year. It is also due to the fact that soil and topographical conditions are such that this is all that is necessary. In British Honduras any produce which could be moved by road up to the present is mainly perishable and has to be transported when it is ready for the market. This means that all-the-year-round roads would have to be constructed if they were to serve their purpose. It would probably be possible to construct such roads on the pine ridge, but this is the most useless soil from an agricultural point of view in the country. To make roads through high forest, which would serve as all-the-year-round roads, would be a very costly undertaking, and in very few places would the quantity of produce make this worth while. Such roads would need proper foundations, and would require heavy metalling if they are to serve a useful purpose, and further, unless they were fully used, the cost of keeping down vegetation on the road surface would be an additional expense. In a country such as this, where vegetation is rank and labour is both scarce and difficult to obtain, it would be a heavy burden on the general taxpayer. Even the initial surveys of road routes would be expensive ; for it is of little use starting out to build a road, unless all the difficulties which are to be encountered are in

the first place realised. Existing trails are not a satisfactory guide. Most of these are old mahogany passes which have been cut in order to give the nearest route to the river, and these have been connected up by rough paths to make what are termed existing roads. Taking the Colony as a whole I do not think that at the present state of development of the country, roads can be afforded.

If money should be available for the improvement of communications it had much better be spent on improving existing waterways than on roads, since the bulk of the good agricultural lands are situated within easy reach of these rivers. When agriculture develops, then there may be a case for roads in certain areas, but at the present time I only came across one instance where a road appeared to be a real necessity, and that was between Punta Gorda and San Antonio. It was among the Indians, in the neighbourhood of San Antonio and Columbia, that I saw the greatest development of agriculture in the whole Colony. Their produce consists mainly of pigs, which have to be taken to Punta Gorda on the hoof, and the trail connecting the end of the metalled road through the Toledo Settlement with San Antonio is, I understand, one of the worst in the Colony, and in places during heavy rains it is so bad that people have been drowned in trying to make their way along it. It is probable that a new alignment would have to be made to avoid these dangerous places. Here also there is developing quite an important agricultural industry in the form of cacao. It may be said that these people already have facilities for water transport down the Rio Grande, but it would be out of the question to provide satisfactory transport for pigs down this river. Pork is at present a large item in the imports of the colony, as this is part of the standard ration for feeding labour. In 1927 the imports of pig products into the colony decreased by nearly 49,000 dollars, and this decrease must in large measure be due to the expanding trade in pigs from this area. I understand that something like 60 head of pigs are shipped weekly from Punta Gorda. The increase of rural population in this area was most marked in the last census reports, and there is no reason why there should not be a continued expansion in the future.

Waterways.—A very large amount of private capital has been sunk in providing means for moving produce by water. There are regular coasting steamship services from Belize, which travel southwards as far as Punta Gorda, and northwards not only as far as Corosal but up the New River to Orange Walk. In addition

to this there are a large number of schooners plying up and down the coast and working up the rivers as far as they are navigable for the carriage of produce, etc., to Belize. The last census return shows that 263 males were employed on water transport work in the colony. In addition to these there is hardly anyone in the colony who cannot handle a dorey, and such a boat is an essential to every dweller either on the cays or along the rivers. On the Belize river there is a well-organised service of motor launches, many of which are specially built for negotiating rapids and shallows. The out-board motor is becoming increasingly popular as a means for expediting river transport, and an appreciable amount of perishable produce is brought into Belize by doreys fitted with these motors. It appears evident, therefore, that the simplest, and possibly the most valuable means by which Government can assist in improving transport conditions is by improving the waterways, especially the *inland waterways* of the Colony. A first step in this direction has already been taken in the construction of the Burdon canal, which will connect up the Sibun river with Belize. At present doreys, conveying produce from the Sibun river to the Belize market, have to cross the bar and travel up the coast for some six or seven miles, and it frequently happens that much of the produce carried is damaged by sea water. The Government also at the present time spend a small amount annually in clearing the more important rivers of timber obstructions. Bomba, on the Northern river, has recently been opened up for schooner traffic by this means. There is much work, however, which could be done if funds were available, such as making the rapids more easily navigable and blasting out rocks which are a danger to river craft. An annual clearing of timber from the river is not all that is required. Trees are liable to fall into the rivers at all times of the year, and the rivers should be kept cleared continually. On the Belize river, boats travelling up stream in the dry season have at several places to haul up rapids. The boats have to put out their anchors up stream and be hauled up by winches. Fixed winches for this purpose would save a vast deal of time and energy.

XI. GOVERNMENT ASSISTANCE TO AGRICULTURE.

British Honduras is one of the few colonies of the British Empire which has not got an Agricultural Department. It has always been regarded as a forest country, and agriculture has been a secondary consideration. The only active interest which the Government has

taken, until quite recently, has been in the employment of an officer trained in horticulture in the West Indies, and this officer was responsible for the formation and maintenance of the small Botanic Garden situated near the mouth of the Belize river. He was instrumental in introducing several species and varieties of fruits and other plants of economic interest, and presumably as a result of this work several of such plants are now distributed throughout the Colony. This officer retired in 1921, and since that time the Botanic Garden has been under the charge of the Forest Department, which was created at about that time.

In recent years there has, however, been a decided change in the attitude taken towards agricultural development. This is probably due in part to the work of the Forest Department, which has been able to evaluate much of the forest areas, and to indicate the extent to which these have been exploited. The decline of the growing industry of planting and exporting bananas, owing to the rapid spread of "Panama disease," which has not only left the growers in a precarious condition without any other alternative crop, but has also placed a heavy burden on the taxpayer on account of the loss on the working of the Stann Creek railway, as well as the favourable reports on trial shipments of locally grown grape fruit, has also added to this interest, and the Government have, with the assistance of the Empire Marketing Board, appointed an Agricultural Officer, who for the present is attached to the Forest Department.

Partly for reasons of economy and partly for expediency, it has been thought advisable not to make a separate Department for the present, and with this decision I am in entire agreement, for this will free the Agricultural Officer to travel over the Colony and acquaint himself with the local conditions, and it will also enable him to make the necessary arrangements to start the essential agricultural stations, about which I shall have more to say later. It will also free him from much office routine and will afford him training in administration work, while in the districts a close co-operation between himself and district forest officers is most essential in a sparsely populated country, where subordinate officers of the right type are difficult to obtain and where labour difficulties are of frequent occurrence. For travelling also the facilities which the Forest Trust possess will be of the greatest assistance.

There are in the Colony three very distinct types of agricultural soil. There is the black loam overlying limestone and marl, which, except

for the pine ridge areas, covers the whole of the north of the Colony as well as the hilly country to the west. There is the heavy laterised coastal clay which occurs along the lower reaches and estuaries of the rivers as well as masking the Toledo beds in the south, and there is the free drained river alluvial loam, which occurs along the banks on the upper reaches of all the rivers which flow eastwards. These soil types correspond fairly closely with the distribution of the rainfall, and the black loams on the limestone are, except in the region of the Indian reserve in the south, situated in areas with a relatively low rainfall, while the other two types are mainly confined to those parts of the Colony where the rainfall is much greater.

I suggest therefore, that two main *agricultural stations* be started, one situated on the corosal areas, in the neighbourhood of Corosal, which will be devoted mainly to arable and mixed farming, and the other in the Stann Creek Valley, where it is thought that an area can be selected in which both the laterised clay and the river alluvial loam are represented. Here the problems will be largely connected with plantation crops such as cacao, coffee, plantains, etc.

In addition to these, the possibility of opening a *small sub-station* adjoining the new Burdon canal should be considered. There is here a large stretch of rich organic soil, at present lying waste on account of the poor natural drainage. It is possible that with a system of drains and embankments this might be developed, in the same way that somewhat similar soils are being developed in British Guiana for the cultivation of Liberian coffee.

This work, however, must be regarded as purely experimental. Everything depends on whether salt water can be kept out and whether tidal action is sufficient to enable drainage to be effected by natural flow. Until the canal is completed it is difficult to say what will happen to the tides when the tidal estuaries of two adjacent rivers are joined together. If such cultivation proves to be possible, there should be good opportunities of developing this area, as it is in close proximity to the town of Belize, which contains more than a quarter of the total population of the Colony, and it is easily accessible either by water or by road. It is, moreover, Crown land, and the development of this area, if possible, would not only be a source of considerable revenue to Government, but would find occupation for the surplus population of the town, and possibly would in time relieve much of the congestion which at present exists there. The

drainage of this area, which would follow development on these lines, would also do much to remove the breeding places of mosquitos, which are very numerous here at present.

The proposed sites for these agricultural stations have been selected after careful consideration both for efficiency of management and control, as well as for economy in time and travelling. In both these areas also there are rest houses where the Agricultural Officer could stay, and prolonged stays would be necessary, especially in the early stages of work, as the local staff will need to be carefully trained, not only in the management of the station, but also in the elements of agriculture.

The following are suggested as possible lines of work which might be taken up at the northern station near Corosal :—

In general, the possibilities of permanent arable agriculture and a suitable rotation of crops.

The possibilities of working sugarcane into such a rotation should not be overlooked.

Improvement in the cultivation of sugarcane with a view (1) to maintaining the moisture in the soil for the more even development of the cane plants ; (2) to increasing the acre yield.

The possibilities of developing tobacco cultivation and investigating which type of tobacco can profitably be grown.

The possibilities of growing Upland cotton. At the present there does not appear to be any scope for this crop in itself, but there is a chance that in the future when agriculture is better developed and labour is more certain, it may prove to be profitable as a rotation crop. Experience in other parts of the Empire have shown the indirect value of cotton when grown in rotation with tobacco by increasing the yield of the following tobacco crop.

The yields of maize, beans, and other crops now grown could probably be greatly increased under better methods of tillage.

As regards permanent crops the locality has a reputation for the production of citrus fruits and has, I understand, a considerable market with Mexico. The possibilities of this should be investigated, as well as that of grape fruit for the European market, as to which there is already a certain amount of local interest being taken.

There is a possibility that Arabian coffee would do well here, and since the type of people in this northern area are more agriculturally inclined and more industrious than elsewhere, it is possible that arrangements could be made to harvest the crop.

The introduction of arable farming will imply the much greater employment of cattle for agricultural operations and the question of growing suitable fodder crops will need to be considered.

It is possible that some of the natural grasses and leguminous plants may prove useful in this respect, and opportunity should be taken to investigate their possibilities when grown under cultivation. A species of *Desmodium* not yet identified, which is known locally as "bread and butter," appears to offer possibilities in this direction.

The improvement of pasture lands also deserves consideration if, as is likely, working cattle are going to take a much larger place in the economy of farming in the future.

As regards the *southern station*, which I have proposed should be situated in the Stann Creek Valley, I must in the first place emphasise the advisability of making this station independent of the Industrial School, since one of the main duties of an agricultural station is to ascertain the labour required and the cost of growing crops, and such information cannot be acquired if only juvenile labour with no monetary incentive to work is employed.

I would also emphasise what I have already stated elsewhere, that in my opinion the future of the agriculture of the Colony must be dependent on the small farmer or settler, rather than on enterprises employing large numbers of labourers. The farmer of this type is working for his own living and what would be absorbed in a large enterprise in overhead charges would assist the small grower in adding to his income.

The following lines of investigation are suggested :—

One of the most urgent lines of work is to see how far it may be possible to introduce cacao into the present system of growing bananas or plantains, by utilising these as an early shade crop for the cacao. In carrying out this work it must be remembered that these trials have not only to suit existing conditions in the Stann Creek Valley, but must at the same time be applicable to such systems of cultivation as prevail in the Sibun and Belize river valleys. These latter two rivers, owing to their proximity to the Belize market, have

a much wider scope, and whereas the farmers in the latter localities can find a market for cocos, yams, etc., the growers in the Stann Creek Valley, as well as in the other river valleys further south, have no such opportunity. The only crops other than these root crops are maize and rice, which can be grown for their own domestic purposes. I mention these subsidiary crops, as they play an important part in establishing cacao. Something more than the rough clearing, which is now often made when bananas are planted is necessary if the land is to come under permanent cropping, and such subsidiary crops will help to pay the costs of such clearing. Stumping will probably be necessary as cacao in other countries has been found to be as liable to "stump rot" as has tea and coffee. This disease is carried to the roots of the living crop from the decaying roots of dead forest trees.

Liberian coffee which is another possible crop for trial cultivation in this area can, if found suitable, be probably established in the same way.

There is, I understand, an increasing demand for plantains for the American market, and if this can be expanded, it is possible that these may replace the banana as a quick money crop. These appear to be immune to the " Panama disease," and are not so particular as regards soil conditions. Better methods of cultivation are indicated in order to improve the quality of the fruit, so that this can compete with the fruit grown in neighbouring Central American republics.

On the red lateritic soils of this valley it is possible that ginger may prove to be a suitable crop, and it is worthy of experimental trial, for if the quality should prove equal to that from Jamaica, it is possible that it will pay to grow. At any rate figures regarding the cost of cultivation are necessary as conditions and costs of labour are very different here to what they are in Jamaica. Black pepper is also indicated as a possible crop suitable for small settler cultivation on these red lateritic alluvial and hillside soils. Experimental work on grape fruit and other citrus fruits may be indicated on the river alluvial soils as the industry expands. At present the commercial side of this work as well as the nursery side is being ably carried out by the Principal of the Industrial School.

In addition to these agricultural stations under the direct control of the Agricultural Officer there are other lines of work which seem to be necessary.

In the first place there should be close co-operation between the Agricultural Officer and the Principal of the Industrial School in the Stann Creek Valley, as I consider that this institution is capable of rendering great assistance to the colony. Already there are considerable nurseries established here for raising and grafting grape fruit for sale to prospective growers, and excellent progress has been made. It is essential that these grafted trees should be of uniform and good quality, and careful examination should be made of the existing trees from which bud wood is taken. This is more especially necessary in the case of the Marsh variety, as there is often bud variation, which causes variation in the shape, size and quality of the fruit. Careful tree-yield records should be maintained of trees with the best flavoured fruit, so that there can be no doubt that the bud wood is being obtained from the best source possible.

Secondly, there is the extension of work from these nurseries. As time goes on the Agricultural Officer will be in a position to advise growers, and he will also be able to utilise the plants raised at these nurseries to the best advantage. For example, I saw a new plantation of grape fruit just planted with 500 trees obtained from these nurseries. The owner of this plantation had not even got the holes dug for these trees when they reached him, and the whole lot were lined out and planted in the one day. This does not give the trees a proper chance, and if there had been proper co-operation between the extension work and the nurseries, these trees would not have been sent till the land was ready for them.

As the trials and cultivation experiments on the agricultural stations begin to give results, there will in all probability be a large demand for plants of such products as cacao and coffee. The raising of these plants is very suitable work for an institution such as this. When this develops there should be further and similar co-operation between the authorities of the Industrial School and the Agricultural Officer.

The Industrial School is a very suitable place for the introduction of bullock-drawn implements, and the training of the working animals, as well as the training of the pupils in handling implements and cattle, will prove of the greatest value to the country, which is entirely ignorant of such work. I have spoken to the Principal on this matter, and he is anxious to make a start. I understand that

his previous experience in this direction will be of the greatest value in making this work a success. It is useful training for the boys, and should be the means of finding many of them employment when they leave the institution.

As I have mentioned already, there are hopeful signs of a local agriculture being developed and expanded among the Indians of the south, and I consider that these people are a distinct asset to the Colony. It is in the Indian reserves that there has been the greatest increase of population in recent years, and I suggest that an officer should be appointed to act as an Indian Commissioner, who would not only have magisterial powers, but would also be a technical officer to look after their agricultural interests. As these agricultural interests are intimately connected with forest problems, the same officer might be in charge of forest operations as well. I have mentioned this suggestion to the Conservator of Forests, and he is of the opinion that such a post might be filled from among his present staff, in place of a forest officer who is stationed here solely for forest matters.

Before this is done, however, it would be advisable to have the frontier between British Honduras and Guatamala definitely demarcated and settled. I understand that the Survey Department have already got the base line measured, from which this boundary can be fixed, and it only remains to get the consent of both interested countries. If such an appointment were made it would simplify the work of the District Commissioner at Punta Gorda, who would then be much more in the position of a Resident Magistrate.

Indirectly, Government could through their Education Department, assist the farmer during busy times of the year by so arranging the school holidays that juvenile labour would be available for such work as sowing, harvesting, etc.

If, as I suggest, the future of British Honduras lies in the direction of developing the small farmer rather than in capitalised agriculture, some modification of the regulations regarding surveys is necessary. All surveys must now be certified by a Government surveyor. These are all theodolete surveys, but something much simpler is indicated for demarcating small areas of freeholds and leaseholds whether held from Government or from private owners.

XII. INFLUENCE OF LAND TENURE ON THE FUTURE DEVELOPMENT OF AGRICULTURE.

The future of agriculture in the Colony, if it is to progress, must be based on *permanency of occupation and of cultivation*, and this brings up the delicate question of land ownership. The map attached to this report shows that the major part of the accessible areas of the Colony are now privately owned.

The statement, in Appendix I, shows that 2,683,371 acres are held on *freehold*. This does not include two properties held on a 99 years' lease, which would bring this total up to about two and three-quarter million acres. Of this acreage of freehold land 96·86 per cent. is held by 96 owners; 2·81 per cent. is held by 546 owners, and the remaining ·32 per cent. is held by 1,006 owners, the average size of whose holdings is only 8·72 acres.

With regard to *leasehold* land, figures for this are given in Appendix II. Excluding two leases of 99 years, the total acreage of leasehold properties amounts to only 27,601 acres, or about 1 per cent. of the total area alienated. These 27,601 acres are held under 1,236 leases by 1,083 different people, whose average holding measures 25·44 acres. Each lease averages 22·37 acres. Allowing that 50 per cent. of the area of these holdings are cultivible, and this is probably a high proportion, it can be seen that a very few of these leaseholders or the small freeholders can do more than make a bare living out of their properties. It is no wonder, therefore, that in a country such as this, where even the elements of agriculture are barely known, there should be such large areas of land along all river frontages which have been cleared for agriculture and then abandoned. The depressed state of agriculture is indicated by the figures given in paragraph 59 of the last Census Report, which show that whereas the population of urban areas has increased by about 89 per cent. in a period of thirty years, the rural population has only increased by 16·6 per cent. in the same time, and that this increase is mainly confined to those districts where the Indian population predominates. If the Cayo and the Toledo districts are excluded, the increase in population in the rural areas has been only 8·8 per cent. in thirty years. In the Stann Creek district there has actually been a decrease, and this has been accentuated, I understand, since the last census on account of the losses incurred on banana cultivation, owing to the ravages

of " Panama disease." In this thirty-year period the increase in population in the rural areas of the Cayo district has been about 32 per cent., and in the Toledo district about 90 per cent.

It is largely true that the rural population have not got any profitable crop to grow on their limited acreages, except food crops for their own consumption and vegetable and root crops and a few fruits for the very uncertain market in Belize. In addition to small freeholds and leases, large freeholders do at the present time lease out land for " Milpa " cultivation on areas where there is no stand of mahogany or other valuable timber, but only at an exorbitant rental of five dollars an acre for small areas and a slightly lesser rate for larger areas, but this is not going to be of much permanent benefit to the country. In the Corosal district also most of the sugarcane areas are grown on land leased from large landholders.

In the main, however, these large tracts of freehold land are kept as private forest reserves, which the owners exploit for their own benefit, either felling timber themselves or leasing out to contractors the rights to do so, or to collect forest produce such as chicle. Only one forestal company have made any attempt up to the present to work their forests on definite working plans, and this only on a portion of their properties. No attempt that I could ascertain had ever been made to lease out land for permanent agricultural operations except for cane growing ; this is perhaps not surprising, seeing that very little interest has been taken in the past in developing such forms of agriculture, and very little is known about how to grow such crops if attempts were made.

Now that so much of the areas of accessible forests have been worked out, many owners are prepared to sell out their properties at a price, but others are holding on to these, merely paying the Government land tax, in the hopes that some crop or some forest product may be discovered which will raise the value of their properties. Nobody, however, is likely to want these large tracts of forest land for agricultural purposes, because only a limited portion of these areas is of any value for agriculture, and since the valuable timber has been worked out, the major portion of these areas would be of little value to the settler or to anyone else.

British Honduras, from an agricultural point of view, is essentially a country for the small settler on account of the scattered and patchy nature of lands suitable for agriculture. The capital of such people

is largely represented in their capacity to work, and unless private owners are prepared to part with land, either by sale or on long lease in small parcels to such people at a reasonable cost or rent, it is difficult to see any future before the country. Supposing such plantation crops as cacao, Liberian coffee, grape fruit, etc., should be found to be profitable, this will at once raise the value of land suitable for growing such crops—in fact the preliminary success of grape fruit in the Stann Creek Valley has already had the effect of raising the asking price for land in some cases more than a thousand per cent.—and if this is overdone it will be more than the people can pay. Government, unfortunately, are not in a position to assist matters, because so much of the valuable land in the Colony has already been alienated that now they are not able to offer any suitable land and so help to control the price. It can be seen, therefore, that a vicious circle is likely to be created.

The Government have employed an Agricultural Officer whose duty it is to endeavour to improve the agriculture of the country. His work must largely consist of finding out what crops can be profitably grown in the country, what acreage will bring in a decent living, and the best methods of growing them. There is the danger that the parties who are most likely to benefit from this work are not so much the future farmers as the small body of large landholders.

Even if some satisfactory way out of this impasse could be reached, there are other obstacles to be overcome. On the one hand, if the landholders are prepared to lease out land on long leases, it is necessary that they should be able to protect themselves with some guarantee that the land is going to be properly developed, and not simply cleared for shifting cultivation and then abandoned. On the other hand, the tenant must be protected in his lease in such a way that, after he has a permanent crop developed, the crop is his property, in so far that if the lease is ended he should be able to get full compensation for healthy trees which are growing on the land.

XIII. CONCLUSION.

In recent years much has been added to the knowledge of the country and its soil distribution by the reconnaissance and topographical surveys carried out by and under the guidance of the Forest Department. Without such surveys it is not possible for anyone to form an idea of the extent of different soil types. Thus,

for example, Morris estimates the area of cohune ridge in the colony at over a million acres, or about one-sixth of the total area of the colony. Dunlop, as recently as 1921, estimates that from one-half to one-third of the northern area possesses soil conditions fit for agriculture. Mr. Stevenson's examination of the Freshwater Creek Reserve shows, however, that of this area only 4½ per cent. is really good agricultural land, and further reconnaissance of this northern area, shows these " corosalitos " of good agricultural land are merely chains of cays or islands of good soil through the forest. As the principal trails through this country follow these chains of cays one would, when travelling by them, naturally form the idea that these were much more plentiful than they are.

This additional knowledge of the country may prove at first sight a little disappointing. In a way it is, but it should have the effect of removing those interests which wish to exploit the country and so enable the people of the country to develop their agriculture without outside interference ; for nothing tends to hold back the standard of farming in a country so much as wholesale methods of farming with hired labour.

Much has been said of the benefits which the large interests in bananas in Central America have brought to those countries. They certainly have brought money into the country and have materially benefitted a few of the larger landholders, but *the bulk of the people have been forced to become mere labourers and they will never be anything more.* In British Honduras there need never be any fear of this, simply because it is difficult to find areas of agricultural land sufficiently large and sufficiently concentrated to make this type of farming successful. It is a country essentially fitted for the development of private enterprise in farming, and it should be possible to develop a type of farming which would produce an ample living. The question remains to be settled how this is to be put into effect, since the bulk of the land is owned by a very few individuals or corporations.

It is certain, if agriculture is to make rapid progress, that the population of the country districts must increase much more quickly than it has in the past. This can I consider be best brought about by the encouragement of bona fide settlers from the more densely populated West Indian Islands. The cohune ridge soils of the north of the colony remind one very much of the soils of Barbados and colonists from there would, if carefully selected, prove a valuable asset to the country, for the people of that island are noted for their

industry and their highly developed agricultural practice. For the south of the Colony, people from other islands should similarly be encouraged. Here the rainfall is heavier and the soil is of a type more commonly found in mountainous volcanic country. It is, however, of little use encouraging immigration until something more definite is known of the agricultural possibilities of the country and until some more satisfactory arrangements can be made than at present exist for placing settlers on the land.

If, as I trust, the Government through their Agricultural Officer can show what crops can be profitably and successfully grown, and if at the same time the way is cleared whereby the farmer, whether he belongs to the Colony, or whether he is a settler from one of the West Indian Islands, can obtain a title to land on reasonable terms, be it freehold, or be it leasehold either from Government or from private owners, there is I consider a certain future before British Honduras as an agricultural country. The initial success of consignments of grape fruit have shown that the produce of the Colony is appreciated on the European markets for its quality. The report on a sample of cocoa published at the end of this report indicates that the country can produce a cocoa as good as, if not better than, Trinidad, provided that proper methods of fermenting and curing are introduced. These are at least two more or less certain crops, while there are several others which may prove to be equally profitable. In addition to this there is the value to the country not only of making it much more self-supporting than it is, but of reducing the cost of living which is one of the main hindrances at present to agricultural development ; for the farmer, no matter in what country he lives, must be dependent on his own industry to produce a large part of his own food requirements.

The general prosperity of the farming community will reflect on the general prosperity of the country as a whole, and one has only to look to the large and prosperous townships of other agricultural Colonies to see how much the farming community contributes to the welfare of the people generally.

Not the least of the benefits which will follow a sound development of agriculture will be the increase in the revenues of the Colony, which will then be in a position not only to consider the opening up of the country with better transport facilities, but will have a much better idea than is now possible of where such improved means of communication should be made. The farming industry itself will indicate this.

APPENDIX I.

Statistics of Freeholders

Size.	Total Acreage.	No. of Freeholders.	Average area held by each individual.	Percentage of Total.
5 acres and under . .	1,842	465	3·9	·07
5 up to 20 acres . .	6,947	541	12·8	·26
20 up to 50 acres . .	8,756	273	32·0	·33
50 up to 100 acres . .	9,240	121	76·3	·34
100 up to 500 acres . .	27,645	120	230·3	1·03
500 up to 1,000 acres .	29,785	36	827·3	1·11
1,000 acres and over. .	2,599,156	96	27,074·5	96·86
	2,683,371	1,652	1,624·3	

From figures supplied by the Internal Revenue Office.

APPENDIX II.

Leases of Crown Land.

(Excluding house lots in town areas and the island of Turneffe).

Size in acres.	Total acreage for each size. a. r. p.	No. of leases.	Average area per lease. a. r. p.
5 acres and under . .	1,558 0 19	338	4 2 17
Over 5 up to 20 . .	5,713 3 13	437	13 0 12
Over 20 up to 50 . .	14,094 2 09	379	37 0 30
Over 50 up to 100 . .	5,224 0 24	74	70 2 15
Over 100 up to 500 . .	1,010 2 17	6	168 1 29
Over 500 up to 1,000 .	——	—	——
Over 1,000 acres . .	32,630 0 00	2	16,315 0 00
	60,231 1 02	1,236	48 2 37
		No. of individual lease-holders	Average area per lease-holder. a. r. p.
		1,087	55 1 26

Note.—Excluding the two leases over 1,000 acres, which are 99 year leases and practically treated as grants, the total are leased is 27,601a. 1r. 02p. held by 1,085 individual lease-holders, making an average holding per individual of 25a. 1r. 30p.

From figures supplied by the office of the Surveyor General.

APPENDIX III.

Report of the Imperial Institute, South Kensington, on Cocoa Beans from Columbia, British Honduras.

Description.

The sample weighed 14½ oz. and consisted of clean cocoa beans, which had been very thoroughly washed. The beans varied in size from small to fairly large, and were generally of a light pinkish-brown tint ; they had been somewhat lightly and unevenly fermented. The break in many cases showed a poor, dull colour, whilst the taste of the beans was somewhat weak and lacking in character. The husks were on the whole fairly easily removed. There were a few grubby, mouldy and flat beans present.

Results of Examination.

The beans averaged 1·22 grams in weight. The husk formed 7 per cent. of the beans. Chemical examination of the nibs gave the following results :—

	Per cent.
Moisture	5·6
Fat	50·8
Ash	3·2

These figures show that the beans were of normal composition.

Commercial Value.

The beans were submitted to two firms of manufacturers, who furnished the following reports :—

(1) " I have had the sample of British Honduras cocoa roasted, shelled, and sorted out, and am sending you three samples which have been produced.

1. In the form of a paste which consists of the beans ground up in a mortar with a pestle.
2. A sample of roasted cocoa beans described as ' Good.'
3. A sample of roasted cocoa beans described as ' Bad.'

The ratio of bad beans to good is about 12 bad ones to 8 good ones.

The beans seem to have suffered very materially during the fermenting and drying operations. In all probability they may have damped back several times before they were finally dried. One would say that the sample should be very much better than it is if more care had been taken in the curing. Consequently, the flavour when roasted is unpleasant. It is very difficult for us to assess a value to it, but one would say that it is not worth more than 45s. a cwt. c.i.f. The price of Trinidad cocoa to-day is returned at about 65s. One would think if the bean was properly cared for under skilful management that it should be capable of ranking along with West Indian cocoa, if not better.

The bean itself seems to be rather of a mixed variety and one would say that it is not so dark in colour as the usual Forastero bean coming from the West Indian Colonies. This is all in its favour as regards commercial value. In all probability the trees themselves have come from a better stock than the sample shows at the present time.

Before roasting, the cocoa showed signs of having been washed after fermentation. If this operation is not very skilfully carried out it has a tendency to lower the value of the bean itself, although for sale purposes on the surface it makes it look nicer."

(2) " The sample of Honduras cocoa is not fully fermented. As manufacturers we always deprecate the process of washing cocoa beans ; we are of opinion that washing is likely to be detrimental as the beans cannot be stored to the same advantage as those that are unwashed, the shell being more liable to break and thus exposed to attack by cocoa pests.

In order to obtain the opinion of the market, we submitted the sample to our London brokers, and they estimate the value nominally at 55s. to 60s. per cwt. landed London, but think the cocoa might realise 70s. to 75s. per cwt. if received in a sound condition."

31st December, 1928.

Published by permission of the Royal Geographical Society.


MAP OF
BRITISH HONDURAS
Compiled in the Surveyor Generals Department
by G. A. Elliott, C.L.S., from notes and surveys
of L. H. Ower Government Geologist
Scale: 1/1,000,000
MILES 10 0 10 20 MILES
Railways Tracks
International Boundary
Reference
Crown Land
Lands alienated and leased
Pine Ridge
Swamp
MEXICO
GUATEMALA
HONDURAS
PETEN
AMBERGRIS CAY
TURNEFFE ISLANDS
GLOVER REEF
Payo Obispo
Corozal
Orange Walk
BELIZE
CAYO
Stann Creek
Punta Gorda
Livingstone
Puerto Barrios
Puerto Cortez
NOTE.
The map is in the nature of a sketch map with no pretention to great accuracy.
percentage of the land being brought into cultivation within five year

E.M.B.17.

SCHISTOSOMIASIS AND MALARIA IN RELATION TO IRRIGATION

By

J. F. C. HASLAM, M.C., M.D., M.R.C.P. Ed., D.P.H.,

Director of Library Services, London School of Hygiene and Tropical Medicine ; Assistant Director, Bureau of Hygiene and Tropical Diseases.

MAY, 1929

LONDON :
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses :
Adastral House, Kingsway, London, W.C.2 ; 120, George Street, Edinburgh ;
York Street, Manchester ; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller.

1929.

Price 1*s.* 3*d.* Net.

70–221–17.

CONTENTS.

(35497) Wt. P2449/546/1725 2,000 5/29 Harrow G3.

PREFACE.

THE importance to the British Empire of more intensive study of the many problems, economic, engineering and scientific, involved in the successful development by irrigation of areas deficient in rainfall was emphasised in one of the earliest publications of the Empire Marketing Board: (*Irrigation in the Empire*, Keen, May, 1927.) The questionnaire drawn up by Dr. Keen elicited a large amount of information from different parts of the Empire and the complexity of the subject suggested the need for an authoritative survey by an expert body. Such a survey is now being carried out by the Irrigation Sub-Committee of the Committee of Civil Research.

Among the many scientific problems involved in irrigation schemes medical and public health questions figure largely. This Report on Schistosomiasis and Malaria in relation to Irrigation has been prepared by Dr. Haslam for the Irrigation Sub-Committee of the Committee of Civil Research and is intended rather as a convenient summary of practical lessons to be drawn from existing knowledge than as an original contribution to medical literature.

At the suggestion of the Committee of Civil Research the Empire Marketing Board is publishing the Report in the hope that it may interest a wider public and prove of practical value to engineers and agricultural experts whose work brings them into contact with irrigation problems.

WALTER ELLIOT,
Chairman of the Research Grants Committee.

Empire Marketing Board,
March, 1929.

(35497) B

SCHISTOSOMIASIS AND MALARIA IN RELATION TO IRRIGATION.

THERE appeared the other day a non-technical but very interesting survey [Carrier, 1928.] of irrigation projects throughout the world. In his glowing account of the wonders wrought by irrigation, the author stresses the disadvantages of drought, and indicates some of the difficulties caused by excessive rainfall ; in the latter connection he refers, rather vaguely, to the relation of swamps to disease. There is a chapter entitled " Some Advantages of Irrigation," and a noticeable absence of reference to any disadvantages. It is remarked that there was a very high mortality among the quarter million men employed by Mohammed Ali upon irrigation works, but no mention is made of the likelihood that the work itself fostered the principal causes of the high mortality.

It is, in fact, worthy of note that books and papers upon irrigation seldom contain any reference to the important disease risks attaching to many of the schemes, both for the labour force engaged upon the works, and for the population resident in the area concerned. Perhaps this is not to be wondered at. It is but recently that medical science has been able to give any useful guidance, and even yet there are gaps in knowledge and uncertainties regarding proper practice which make it difficult to combine preventive hygienic measures with practical engineering propositions. An endeavour has been made here to gather together information which may help towards the provision of the benefits of irrigation without the spread and perpetuation of serious disease risks.

In 1920 it was estimated [Keen, 1927.] that 7 per cent. of the total cultivated area of the earth was farmed by irrigation. Since then this area has been added to enormously and is still growing yearly, as is to be expected from the facts of the case. In Keen's words : " It is not generally appreciated that nearly one-third of the earth's surface [coloured white in Map I] receives only 10 inches of rain or less annually, and that over one-third [blue in Map I] the rainfall is between 10 and 20 inches. . . . . on land receiving less than 10 inches annual rainfall, irrigation is generally essential if any form of profitable crop production is to be undertaken." Even those areas receiving up to 20 inches of rainfall require additional water for intensive crops, and the seasonal incidence of the precipitation may make it desirable to have a system whereby water may be supplied artificially at will. Throughout the blue and white area in

Map I many irrigation systems are in use, and fresh ones are likely to be considered, and in much of that area the diseases under discussion are present or capable of being introduced.

Both schistosomiasis and malaria are caused by living parasites. In each case the parasite, while passing part of its life history in man, requires, for the completion of its cycle of development, a second (intermediate) animal host. In both cases it is impossible for an infected person to pass his disease to another by contact, by fouling of food, or air, or directly by contamination of water. In both cases, for the spread of the disease from one person to another, it is necessary that the parasites should pass from the human (definitive) host to the particular intermediate animal host, should there go through certain developmental changes, and should then enter the body of another human being. In both cases water is a *sine qua non* in this chain of events. In this necessary association of water with the conditions required for the spread of these diseases lies their relation to irrigation. Apart from this essential similarity, the association of water with schistosomiasis differs widely from that with malaria. The two diseases are, therefore, considered separately.

Schistosomiasis.

The disease is ancient ; indisputable evidence of its occurrence has been found in mummies of the period 1250–1000 B.C. It is serious. There has been said of it [Ibrahim, 1927.] : " It is undermining the constitution of the vast majority of the population, and causing a great deal of suffering, disability and loss of life " ; and of the disease of the Far East [Houghton, 1920.], " Thousands of farmers yearly . . . . either succumb to an overwhelming infestation, or are compelled by increasing weakness and disability to become a burden on their families and the community." It has been estimated [Griesinger, 1854.] that schistosomiasis is responsible for 25 per cent. of all deaths in Egypt. More recent observers, however, give a lower figure.

The geographical distribution of the disease is wide ; it is shown in Map II*, and Appendix I contains a bibliography of its reported occurrence. In respect of a few places from which cases have been

* Since the map was made it has been shown (Raynal, J., *Ann. de Parasitol.*, 1929, *v.* 7, 10–28) that the disease occurs over practically the whole of the Island of Madagascar.

reported, there is some doubt as yet regarding the existence there of a proper intermediate host. The existence, however, in such places of clinical cases of the disease, and the concomitant existence in many of them of conditions known to be favourable to the intermediate host, warrant the recording of the cases in order that further study may determine the presence or absence of risk of spread.

In many countries the incidence of the disease is heavy; in Egypt it is intense. Ali Bey Ibrahim (*loc. cit.*) says: "In a typical locality . . . . . 85 per cent. of the agricultural population and 54 per cent. of the proprietors and artisans are suffering from infection with *Schistosoma haematobium*, while *S. mansoni* affects in the same locality 51 per cent. of the former class, and 8·7 per cent. of the latter." And he adds, remembering microscopical examination to be not infallible, "it can safely be said that all hands engaged in farming . . . . are infected."

The disease is caused by a trematode worm (fluke) of which three species occur in man (1. *Schistosoma haematobium*, 2. *S. mansoni*, 3. *S. japonicum*). The worms themselves are to be found in the small veins; for the most part, of the pelvis and lower abdomen. The serious pathological results of infection are attributable to the irritation caused by their eggs, which are hard-shelled, and, in the case of two species (1 and 2) spiked; there is, however, evidence of some toxic effect as well.

The effects of this irritation are manifested chiefly in the lining membranes of the urinary bladder and the lower bowel, into which the eggs penetrate from the tiny veins. One of the common names of the disease, endemic haematuria, has reference to the passage of bloody urine, a common and obvious sign of infection with *S. haematobium*. The parasite of schistosomiasis of the far East (*S. japonicum*) causes serious damage to the liver and spleen.

The eggs of the worm leave the human host in the urine or faeces or in both; if they do not reach water they die. On reaching water they hatch in a few minutes, and there emerge the actively swimming embryos (miracidia) which can live only in water. Even there their existence is but brief (about 24 hours) unless they can find and penetrate the particular intermediate host which, for all three human schistosomes, is a fresh water snail.

Several snails of different genera and species* have been convicted of playing the part of intermediate host to human schistosomes; all are aquatic and die on drying. Their natural habitat is fresh water in ponds, slow-running streams, marshes, and the like. Vegetation in the water provides both shelter and food. The snails are said to be favoured by the presence in the water of human or animal food-waste [Cawston, 1926.], and the same worker in the paper quoted and elsewhere has worked out, for *Physopsis africana*, the favourite food vegetation. They can survive in solution of sodium chloride less concentrated than 1 per cent.

In the body of the snail the miracidium goes through essential developmental changes and multiplies very greatly. After a period whose length is influenced by the water's temperature (shortened by rise of temperature), the parasites, in new form, having two-lobed tails and now called cercariae, begin to emerge from the snails, and an infected snail may continue to discharge cercariae for at least some weeks.

The cercariae can live in fresh water only, and in this they die within 48 hours, continued existence being possible only to such of them as, within that time, gain entry to man, there to grow into worm form. (Certain other vertebrates can be experimentally infected with *S. haematobium* and *S. mansoni*, and some domestic animals are naturally infected with *S. japonicum*†). The passage of cercariae from water to man takes place by rapid penetration of the skin of any part of the body immersed in contaminated water or by penetration of the mucous membrane of the mouth when infected water is drunk.

In the course of some months after penetration of the skin or mucous membrane of the definitive host, the cercariae grow into the fully developed worms, male and female, which are found, the former folded on itself and embracing the latter, in the small veins, there producing eggs and so continuing the cycle.

---

* *Bullinus contortus, B. dybowski, B. innesi, Planorbis boissyi, P. corneus* (*var metidjensis*), *P. sudanicus, P. neosudanicus, P. olivaceus, P. centrimetralis, P. guadelupensis, Physopsis africana, Melania nodocincta, Oncomelania nosophora, O. hupensis, O. formosana.*

† Since this memoir was written it has been shown [Cameron, 1928.] that in the island of St. Kitts (Brit. W. Indies) the imported, but now wild, African monkeys (*Circopithecus sabaeus*) are naturally infected with *S. mansoni*. If monkeys or other animals are found to be naturally infected in other countries, e.g. the continent of Africa, the problem of eradication of schistosomiasis will become more difficult than ever.

It will be noted, in the case of this parasite, that water is essential for the hatching of the eggs ; for the free swimming life of the miracidium which emerges ; for the life of the intermediate host ; for the life and infective activity of the cercariae coming from the snail. In other words, water is necessary for the existence and multiplication of the intermediate host, and also for the life stages of the parasite which occur between man and snail, and again between snail and man. Some emphasis has been placed upon this, for the case of malaria is very different as will be seen later. A full account of the researches which confirmed the life history of human schistosomes will be found in the *Journal of the Royal Army Medical Corps*, [Leiper, 1918.].

It follows from the foregoing that schistosomiasis can only spread and occur endemically in those localities where the snail intermediaries are to be found, and where they are liable to be introduced. It follows, too, that contamination, by human excreta, of the water containing the snails is a necessary condition, and further, that contact with or drinking of contaminated, snail-containing water must take place for infection to occur. Given the contamination of water, the presence of the snails, frequent working or bathing in and drinking of untreated water, it follows that the more widely distributed is such water in any area, the more widespread and intense will be the incidence of schistosomiasis.

There almost seems to be an element of perversity in the actual situation. In many of those localities where agriculture is the only possible means of support of the population, and where water is therefore in great demand, and in many of those places naturally barren but offering great reward to the irrigator, the circumstances are such that only the spread of water over the land is required to complete an ideal condition for the propagation of schistosomiasis.

The circumstances of the agriculturalist's labour are such that it is inevitable that he will pass his urine where he works, and probably his faeces as well. Thus the possibility of what may be called accidental contamination of water with schistosome eggs is in any case considerable. Maps I and II bring out the fact that in a great part of the areas where irrigation is desirable, and where this fluke disease has been recorded, the people are Mohammedans upon whom their religion enjoins the washing of the parts after the passage of excreta. The labourer therefore urinates and defecates in proximity

to water, and the liquid used in the ablution flows back into the channel whence it was drawn. This is additionally dangerous, because it is at the end of the act of passage that most of the eggs pass out, at the very moment when washing water is applied. Apart from this special difficulty arising from the teachings of religion, it will be realised that the standard of education and habits of the field labourers in the areas where schistosomiasis is found are not such as to provide hope, at least for long to come, that any particular care is likely to be taken to avoid contamination of water by excreta.

The snail intermediaries are found in very many of those countries where the extension of crop-bearing lands by means of irrigation seems most desirable and most likely to be profitable. It must be remembered too that in some places where huge irrigation schemes are in use or projected (India comes to mind in this connection), although the particular snails have not yet been shown to be present, climatic conditions are suitable for their multiplication if introduced and natives of India, infected elsewhere, may return and start an endemic focus.

As for acquiring the infection from water, everything seems to favour it. Agriculture necessitates working in water. Schistosomiasis is a disease of warm countries, and what more natural and certain than that, in such places, both the labourers and their children should drink freely of, and bathe frequently in, the nearest water to hand.

The circumstances being what they are, modern irrigation, as has been said, can hardly fail to encourage and increase the spread of schistosomiasis. The greater the area irrigated, the more numerous the breeding grounds for snails, the greater the infective zone, and the greater the number of persons receiving and then passing on infection. The older basin irrigation was less dangerous. The possible area of operation was less, and the annual drying, after flood season was over, killed most of the snails and limited exposure to infection to a part of the year. This seems likely to be replaced to an increasing extent by perennial irrigation, which is more dangerous as well as more profitable.

The following passage from Leiper (*loc. cit.*) well states the position : " The extension of perennial irrigation has resulted in a marked increase in the prosperity of the people of Egypt. The population has again risen to over 12 millions. At the same time, perennial

irrigation appears to have encouraged the spread of bilharziosis.* The disease is much more common at the present day in the Delta and in the Fayum than in those parts of Upper Egypt still supplied only with basin irrigation. This has been remarked upon by Milton. In the Records of the Egyptian Government School of Medicine for 1904 he states :—

> " Cairo is on the dividing line between Upper Egypt and the Delta, and patients come to Kasr-el-Ainy for treatment from all parts of the country ; still the disproportion between the number of cases of bilharzia drawn from the two natural divisions of the country is so very marked that there must be some very well-defined cause constantly acting, and this, I believe, is to be found in the way in which water is supplied to the different provinces for the purposes of irrigation. The provinces of Lower Egypt are supplied with water for irrigation all the year round, or practically so, whereas the Upper Provinces are supplied with water for irrigation only during and after the time of High Nile. Thus, the peasant from Lower Egypt has a much longer period of time during which he is exposed to the chance of infection, and infection is more frequently repeated than is the case with his brother of the Upper Provinces.
>
> " The province of Ghizeh is a case very much in point, for here, although it borders immediately on Cairo, and although Cairo is its hospital town, the proportion of its population per 100,000 coming for treatment for bilharzia is but 9·75 as compared to Sharkieh 19·85, Qalioubieh 18·06, and Menoufieh 13·47, the three other provinces adjoining the capital, but then Ghizeh is basin irrigated."

" The relative frequency of bilharziosis in perennially irrigated areas may be due in part to continued liability of the workers to infection as suggested by Milton, but the favourable environment created for the propagation of the intermediate host is probably a much more important factor."

Ali Bey Ibrahim also (*loc. cit.*), at a much later date (1927), writes : " A comparison of the maps of irrigation with maps of the incidence of bilharziosis (schistosomiasis) will clearly show that where the basin system of irrigation still persists, bilharziosis is at its lowest.

* An old name for Schistosomiasis. Bilharz was the discoverer of the cause of the disease.

. . . . In Kem province of Upper Egypt the incidence . . . . is about 20 per cent. The province is irrigated by basin system. One locality in the province, however, is under perennial irrigation by means of a pumping plant. . . . The incidence of infection in that locality . . . . is 75 per cent." The same author adds that in areas of basin irrigation the only land watered all the year round by special contrivances is the small plots devoted to fruits and vegetables. In such places schistosomiasis is known, as it was in ancient Egypt, as a disease of gardeners.

One striking example from actual experience [Khalil, 1926.] sufficiently illustrates the part that irrigation works may play unintentionally in introducing and perpetuating schistosomiasis in serious form in an area hitherto free from it, and among people only lightly if at all infected.

The place was Kom Ombo in Assuan Province, Egypt. Here the Nile Valley widens, the hills receding to leave a wide plain of some 100,000 acres about 40 feet above the level of high Nile. The plain was dry and barren, and schistosomiasis was, of course, absent. Near at hand, where the Nile Valley is narrow, a small strip of land was cultivated by the villagers by basin irrigation, one crop a year being raised, and schistosomiasis was present but not severe among the people, owing to the periodical drying. The possibilities of this great plain attracted a group of capitalists among whom was the late Sir Ernest Cassel. About 1904, canals were dug, pumping machinery was installed, labour was recruited in the neighbouring villages and housed in the locality. Now the plain has about thirty-five villages with a total population of about 30,000, and 20,000 to 30,000 acres are now *continually* under cultivation, two crops a year being raised.

Recently Khalil has examined the people of Kom Ombo for schistosomiasis ; 70 per cent. were found to be infected. Among agricultural labourers the figure was 75 per cent. To test whether infection had been acquired in Kom Ombo, or in original residential districts, children who had been born and bred in the area were examined. Among them well over 80 per cent. were infected. Confirmation that infection was the outcome of contact with infected canal water was obtained by comparing the findings in an elementary school with those in a school for better-class children. The children in the latter, who do little, if any agricultural work and particularly the girls (who do little bathing in canals) showed very much the lower percentage infected.

An attempt was made to ascertain whence had come the *Bullinus* snails which are now numerous in the canals in an area formerly arid, and the means by which they had been transported. No conclusion was reached. It is possible they came from the Nile *via* the pumps, for though not commonly found in the Nile itself, it is known that the river occasionally transports them. Perhaps they are multiplying behind the Assuan dam. When Khalil searched there, the dam had recently been allowed to fill, and the occasion was inopportune to settle the point. Khalil adds : " It is known, however, that snails may be carried as ova or young, on the feet of migrating birds, and once they are implanted in a suitable locality, they multiply to an enormous extent."

On account of the benefit it brings, irrigation must go on, and its maximum advantages will be sought by the employment of continuous, perennial watering. What, then, is to be done to limit the ravages of schistosomiasis ? Before proceeding to a consideration of any modification of irrigation methods which may limit the spread of schistosomiasis among an agricultural population, it is convenient here to draw attention to those methods of prevention, of interest to those in charge of irrigation works, which are applicable for the control of schistosomiasis among the employees engaged in operations.

In recent years it has become possible effectively to treat those infected with the disease, so that besides bringing about an amelioration of the sufferings of individuals, it is now possible, by mass treatment, greatly to reduce the number of persons discharging living eggs of the parasite, and thus considerably to lessen the volume of contamination reaching the water. There are obvious difficulties in the way of organization of mass diagnosis and treatment throughout a wide and heavily infected country, but the method is perhaps capable of being effectively employed among the labourers recruited for large engineering works, and might be the means of preventing the heavy infection *ab initio* of an irrigation system. Major B. H. H. Spence suggested the use of this method, in addition to precautions against other diseases, at the Wady Halfa quarantine station for examination of labourers recruited in Egypt for work on the Sennar irrigation scheme in the Sudan, but " The Central Sanitary Board, however, decided to allow them in without treatment pending the opening of the canals" [Spence, 1924.]. The treatment takes four weeks to complete, which, in the case of labour recruits, would probably mean their detention for that time at some sort of quarantine station. Nevertheless, there is reason to believe that the

diminution in subsequent sickness and invaliding which would result would repay the difficulties and expense of such preliminary treatment. Although unsuccessful in his suggestion for application of this method to the Sennar labourers, Major Spence persuaded the authorities to apply it to police recruits despite early objections by the Commandant and others. "The improvement in health of the recruits was so dramatic that within six weeks the entire permanent staff . . . . of the Police School asked to be examined and, if necessary, treated. . . . The Commandant (who was at first an opponent) stated that he had never before seen any batch of recruits remain so fit under training. . . . His Majesty King Fuad I of Egypt . . . . gave immediate orders for the rank and file of the bodyguard to be examined and treated forthwith" [Spence, 1925.].

The spread of knowledge, by usual propaganda methods, may help to lessen fouling of water and avoidable contact with infectious water. Some help in this may be obtained from religious authorities, for many ignorant labourers, meticulous in observance of the injunction as to ablution, are quite unaware that fouling of water supplies is forbidden by the Mohammedan religion. Suitable latrine accommodation is required close to houses, and also to work whenever the latter is possible. Control must be exercised over drinking and washing water by localization of drawing to safe and protected places, or by supply of water known to be from a safe source, or which has been made safe by 48 hours' storage or otherwise. The supply of safe drinking water at the site of work is a necessity. Chlorination of water is now very general all over the world, and apparatus for the continuous application of the gas is available, so that, where chlorination is being undertaken in any case, it may be convenient to destroy the schistosome cercariae by this means, and so avoid the difficulties inherent in storage of large quantities for 48 hours. If this is to be attempted it must be remembered that the one part of available chlorine per million, acting for half an hour, sufficient to destroy typhoid and dysentery germs, must be doubled in order to kill the cercariae, and this will necessitate subsequent dechlorination.

Among the members of a labour force, preventive measures may be economically possible, and capable of enforcement by means of sanitary police, which would be totally impracticable where a large population is in question. A knowledge of the life history of the schistosome parasite indicates several points in the cycle where it

would seem to be possible to break the chain of events. Stoppage of the discharge, by human sufferers, of the eggs has been dealt with above. It may be added that in Egypt organization of treatment campaigns has already made great headway.

Among the general population who suffer from this disease it is manifestly impossible, at least for long to come, to stop, or even effectively to limit, the contamination of water channels by excreta. In towns, infection is mainly acquired from the untreated piped water; for the destruction of the cercariae in this the town health authorities are responsible. In the country districts there is no possibility of avoiding work in water, and no likelihood of stopping the bathing and drinking here, there and everywhere, which lead to infection. This narrows down the preventive possibilities to an attack upon the parasite during its stages of development in the intermediate host by destruction of as many as may be of the snails. It is here that co-operation between health department and irrigation department is vital in planning and executing the attack. The aim is to destroy the snail hosts without interfering with crop raising.

Periodical drying of small canals and drains, by shutting off the water, is effective in killing all snails except those which manage to survive in such small collections of water, due to irregularities in the canal beds, as do not disappear by evaporation before the water is turned on again. It is the general rule that irrigation systems are under the control of some central authority which has the power to regulate the supply of water, and it is common, if not universal, practice for the supply to be cut off from time to time, and for some days at a time, during the season when replenishment of the reservoir does not occur. This drying of all the small supply canals and drains will kill great numbers of snails, particularly if the periodical cleaning out of weeds and silt can be made to coincide with it during the season of least rainfall and most rapid evaporation. The collections of water left in depressions can be dealt with by chemicals as will be described below.

This periodical drying can take place regularly without detriment to most crops. Indeed, Keen (*loc. cit.*) shows that from the agricultural point of view, " far from any advantage being gained by over-liberal supplies, the reverse is true." Keen draws attention to the results of experiments in India " showing either a definite advantage, or at any rate no disadvantage, in reducing the total amount

of irrigation," as regards the crops gathered, and comments on the obvious economic advantages of saving water which would enable a wider area to be cultivated.

In Egypt, during the "summer rotations," the water is supplied for six days and shut off for fifteen. There seems to be a fairly general belief that rice is harmfully affected if its supply of water is intermitted to an extent which permits of the field drying, and Leiper (*loc. cit.*, p. 67) appears to exclude summer rice-growing areas from those where snail destruction can be effected by means of the "rotations." That there is room for further enquiry is indicated in a statement from Madagascar [Couvy, 1925], [Galtie, 1913] to the effect that the five varieties of rice used in Madagascar can be sown where they are to be reaped (i.e., without cultivation in a "nursery" and subsequent planting out) and do well without constant irrigation. Galtie states that rice fields entirely unirrigated, receiving no water but rainfall, produced crops as heavy as have the neighbouring irrigated fields.*

The use of an alternative route for the water from secondary canals to the fields might assist arrangements for drying from time to time those smaller channels which are the snails' favourite breeding ground. Leiper has suggested, and Khalil at a much later date repeats the proposal [Khalil, 1924a] that once the smaller canals have been freed from molluscs by drying or other means, fresh access of snails may be prevented by covering the intakes from main canals with wire sieves of about the mesh of mosquito gauze.

Ali Bey Ibrahim (*loc. cit.*, p. 707) thinks the unevenness of canal beds will prove too troublesome for the "rotation" drying to be effective, and he points out that with the rise of the Nile, which occurs in the summer when real drying might otherwise be hoped for, the sub-soil water rises so high that the drains never really dry. He makes more drastic proposals, namely, that the country should be divided into four districts, and that each year irrigation water should be *completely* cut off from the land in one of these areas for the three summer months.

Khalil, writing of the Kom Ombo area (referred to on p. 14) says it has been proposed to increase the pumping by 20 per cent., thus creating in the small canals a current sufficiently fast to be inimical to the snails, the water in excess of crop requirements being led back by drains to the Nile.

---

* And see McCarrison's work referred to in Appendix II, p. 51.

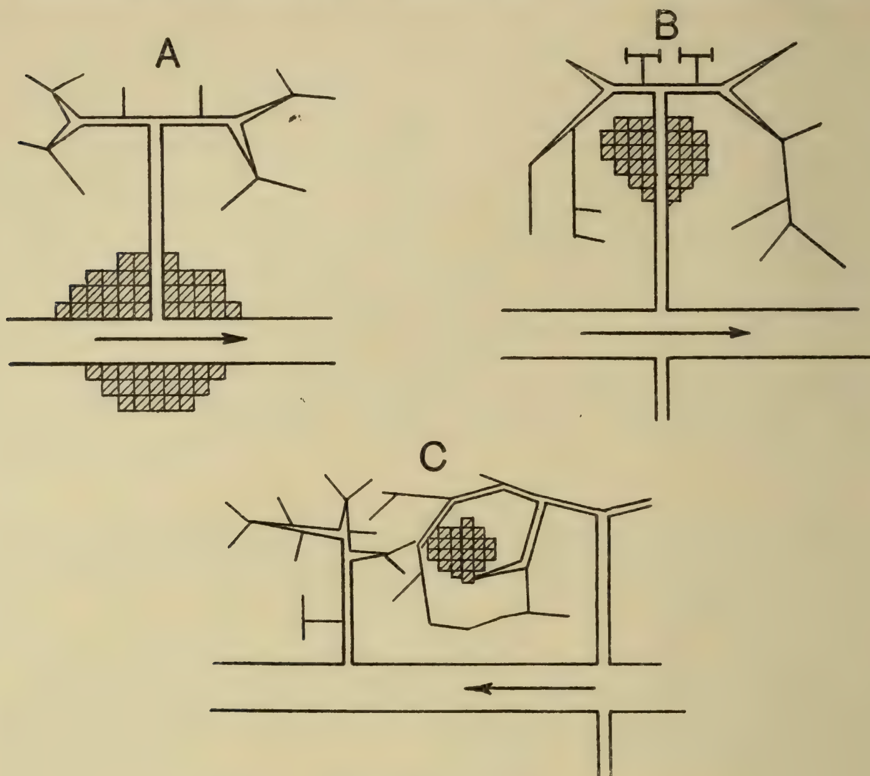
Referring to the drains which take off water after it has circulated to the growing crops, Leiper (*loc. cit.*, p. 69, *et seq.*) points out that these open channels receive less attention than do those bringing the water, and so become overgrown with weeds which interfere with drying. Where open drains are employed, periodical clearing of them is an essential part of any scheme for prevention of schistosomiasis. He considers that underground drainage by unjointed porous pipes (as in England) has not received proper trial in Egypt. Experiments in washing salted land have given ground for believing the method would be successful. Cost is the bugbear, but the expense of cleaning open drains would be saved, and Leiper quotes an ingenious calculation by Lang-Anderson which shows that the value of the land recovered for cultivation by closing the drains would more than recoup the outlay on pipes. It is suggested, also, that the "mole drain plough" is a cheap and efficient method of drainage which is suitable for the soil of Egypt, and will assist in eliminating the haunts of molluscs.

Referring to the extension of irrigation schemes to new areas Leiper (*loc. cit.*, p. 76) makes valuable suggestions which are worth reproducing in full.

"(1) If the banks of main canals or drains are used as roads, the water should be adequately protected from contamination. If possible, however, the roads should run between the terminations of two systems of tertiary drains.

"(2) Villages should not be made on the main drains or on the primary or secondary canals. They should be located as far as possible between two tertiary canals. A glance at Figure 37 A shows at once that where the village is on the bank of a main or secondary canal, the bilharzia eggs and embryos carried on in the main stream passing through the village are liable to infect all the tertiary canals supplied from the canal in the section down stream of the village. This arrangement one sees frequently on the Suez section of the Sweet Water Canal. Where the village is on a tertiary canal (Fig. 37 B.) as happens at El Marg, the water passing through the village is dissipated on the surrounding fields, so that the area of infectivity of the village is limited practically by its own communal boundaries. Where a village lies between two tertiary canals, as in Fig. 37 C., the liability to contamination of the water channels is

practically restricted to those paths leading from the village, and such branches as are used for washing and other domestic purposes.



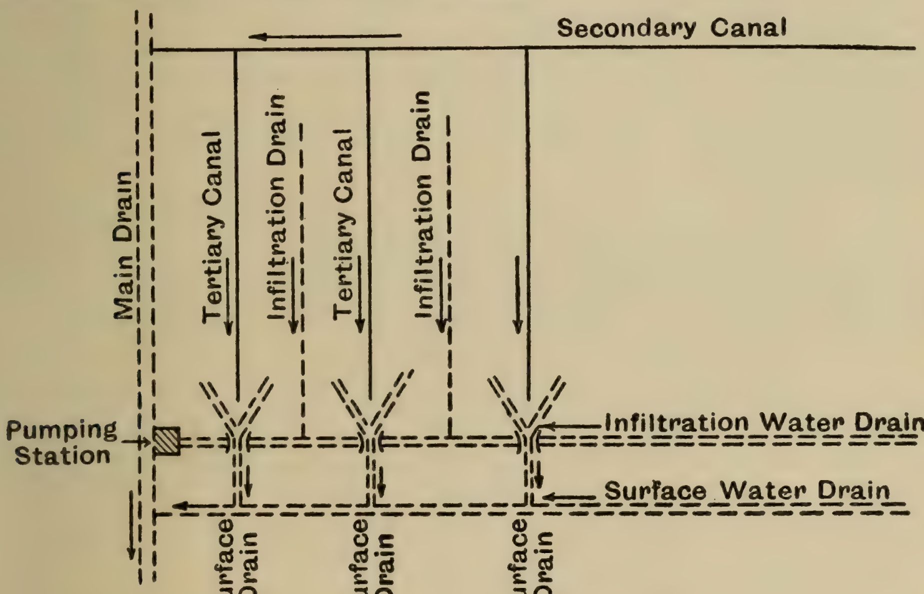
Figs. 37A, B and C.

" (3) The village water supply should be derived from " Sakias" or deeper wells. Each irrigation unit should possess paired supply canals and drains, so that these may be alternately dried without interfering with the irrigation. At Marg, when the canals became practically dry during the rotations, a certain amount of water was drawn from a Sakia in the middle of the village. On one occasion, when the shortage was becoming serious, a neighbouring land proprietor diverted a generous supply of clear artesian water into the Marg Canal. This, however, revived enormous numbers of molluscs which otherwise would, undoubtedly, have been killed by drying before the completion of the rotation cycle.

" (4) Surface-water drains should be reduced, as far as possible, by the utilisation of infiltration drains.

"The Mosséri system of field drainage, which is said to be simple, economical, and extraordinarily effective, seems, of the various systems of land reclamation at present in use, to be the one most likely to produce those conditions that are unfavourable to the spread of bilharziosis.

"Its dual system of "collecting" drains affords more complete control. From the section shown in Fig. 39*, it will be apparent that the bulk of the surface water, after irrigating the land, rapidly drains by a separate surface drain into the main drain, while the water which has soaked into the soil has been drawn off by a deep infiltration drain to be pumped later into the main drain. The surface water drain can therefore be readily sterilised during the summer by drying, while, if need be, the deep infiltration drain can be treated with chemical agents, or periodically cleared.



Mosséri System of irrigation and drainage
(reproduced from Leiper, *loc. cit.*).

"*Administrative.* If a campaign against bilharziosis were commenced on the lines here proposed, it is evident that the whole scheme should be under the charge of a medical zoologist who should be attached, not

* Not reproduced.

solely to the Public Health Service as in ankylostomiasis campaign, but also to the department of Irrigation. In this way only could the full and continuous effect of the present administrative control of the Nile water be brought to bear upon the bilharzia-carrying molluscs so as to ensure their permanent eradication from lands now heavily infected and their exclusion from new areas about to be reclaimed."

The use of chemical reagents for destruction of snails has an interest for those concerned with irrigation, for it may be possible, by their employment, to simplify, and perhaps to avoid, any modification of existing water supply and distribution. Copper sulphate in high dilution is lethal to the snails and harmless to the crops. It has an obvious application in the pools which are left in canal beds after the water supply has been shut off. The use of copper salts and other chemicals, both as regards effects on crops and action on snails, has been investigated in some detail with a review of the literature [Khalil, 1924 b.]. For copper sulphate a concentration of 1/200,000 seems to be necessary in canal water. Much higher dilutions of colloidal copper are effective, but hitherto have been too costly for practical employment.

Ammonium sulphate is commonly used as a manure, and Leiper states that dilute solutions of this are lethal to the snails (he does not state maximum effective dilution) and suggests that on account of its manurial value the salt might be used " without ultimate loss."

At Kom Ombo, Khalil proposed to add to the canals, while in use, copper sulphate in the proportion of 1/200,000 on each day for five consecutive days, and to do this twice in each year. He estimated that each treatment would cost £500 [Khalil, 1926.]. He reported [Khalil, 1927.] that in Oasis Dakhla the addition of copper sulphate continuously for four days and four nights resulted in the death of Bullinus snails ; the district was re-examined six months later when no living Bullinus snails could be found.

Several observers have reported that the snail hosts of schistosomes are not found where decaying vegetation abounds. Cawston states (without details) " the crushed roots, unboiled, of *Tephrosia macropoda* or *Tephrosia bogelli* are very fatal to fresh-water snails, and as one in 25,000,000 of the former species is said to destroy fish in one hour, the local species . . . would appear to be considerably more effective than copper sulphate in freeing pools . . . . of

bilharzia infection. . . . The active principal of Tephrosia would appear to be one hundred times more effective . . . . than the more extensively recommended copper sulphate" [Cawston, 1928.]. The plant Tephrosia is said to be widely distributed in South Africa, and to be very easily grown. Possibly these roots will come to have an important place in combating the snails, but, since Cawston, in the source quoted, gives no more information than the above, and no protocols of his experiments have been found in other publications, the claim of Tephrosia roots to superiority over copper sulphate seems to require confirmation. The same writer [Cawston, 1925.] also says that slaked lime is "of even greater value" than copper sulphate, but fuller evidence of its effectiveness than has yet been brought forward is desirable.

It is clear that the methods suitable to one country or district cannot always, if ever, be applied *in toto* to another. The peculiarities of each place will call for arrangements which will achieve the end of killing the snails without undue interference with agriculture. Much has been said about Egypt; this is inevitable, for the problem has received more attention there than elsewhere. It is unnecessary here to enter into the detailed analysis of Egyptian agricultural needs and methods in relation to combating schistosomiasis which Leiper makes in the monograph so frequently referred to, but his consideration of the problem in all its bearings can be consulted with profit by those confronted with schistosomiasis in *any* irrigated country as a guide to the framing of a policy for the control of that disease.

If the life cycle of the parasite and the habits of its intermediate host are studied in close relation to local circumstances a successful plan of campaign can be evolved.

Malaria.

This disease, also, is of great antiquity. It was well recognised among the early Greeks; and it has been suggested that the dramatically sudden destruction of the hosts of Sennacherib before Jerusalem was attributable to an outbreak of malaria.

The seriousness of malaria admits of no doubt. The disease is capable of the most alarming manifestations. At its worst—as when it devastated Mauritius in 1867 and 1868, causing 32,000 deaths—it ranks with the plague itself. But it is malaria's power of causing

frequently repeated illness, of sapping physical and mental energy and so leading to chronic invalidism and poverty which gives it a high, if not the highest, place among what Balfour has called the "Imperial maladies"—maladies capable of affecting the weal of empires [Balfour and Scott, 1924]. The same authors quote the words of Shipley, in whose view malaria "closed the continent of Africa for countless centuries to civilization and . . . . played a dominating part in destroying the civilizations of ancient Greece and Rome."

The world distribution of the disease is exceedingly wide. (*See* Map III*.) There is current a mistaken belief that malaria is a disease of tropical lands alone. This is not the case; indeed, there has long been in use the term "tropical malaria" for the special type of the disease characteristic of warm climates. It is no longer indigenous in Scotland, Ireland or Wales, but has been contracted in England in very recent years. It occurs quite commonly on the continent of Europe, even in Holland, the Baltic lands and Russia, and those who served in the Army in Macedonia will recall its powers for ill in Southern Europe.

Throughout the tropics and sub-tropics the disease is so generally present that its absence from any place calls for special enquiry into the circumstances which exclude or control it.

Malaria is caused by a parasite belonging to the most humble of the living things classed within the animal kingdom (protozoa). In man the parasite lives in the blood and within the red corpuscles of the blood, and man is the only known definitive host for this parasite. Three varieties affect man, *Plasmodium vivax*, *P. malariae* and *P. falciparum*, the last-named being that especially associated with malaria in the tropics and with the dreaded blackwater fever, the complication of malaria for long (and still by some) believed to be a distinct disease.

The parasites cause their effects by actual destruction of the blood corpuscles within which they live and also by the effects of some poisonous product of their existence; they cause, too, serious injury to the liver, spleen and other internal organs and sometimes, by their very numbers, block the small blood vessels of the brain.

The parasite is capable of multiplication within the blood, but this cannot go on indefinitely, and completion of the life cycle can only take place in the body of an intermediate host. The habitat being

* The island of New Caledonia is incorrectly shown as being malarious.

the blood, there is no convenient natural exit for the parasite as by the excreta in the case of the schistosome. If the parasite cannot reach its intermediate host one of two things must happen. Either its human host overcomes and destroys it, or it gains the upper hand, kills its host and dies with him. But nature has made strange provision for the continuance of this lowly form of life. Its intermediate host is a blood-sucking mosquito which, while feeding, draws up, along with blood, the sexually differentiated forms of the parasite.

These unite in the body of the mosquito, developmental changes and enormous multiplication follow ; the new parasites find their way to the salivary glands of the mosquito, ready to pass down the proboscis into a new victim of the mosquito's thirst for blood.

This cycle is as *necessary* for the transmission and spread of malaria as was the snail cycle for spread of schistosomiasis. Every mosquito will not serve. All malaria transmitters belong to the genus *Anopheles*, of which most species are efficient intermediaries ; and it is only the female which sucks blood and so completes the chain of events. It is to be noted that efficient intermediary mosquitoes are even more widely distributed geographically than is indigenous malaria ; there are thus places and countries, not now malarious, which are capable of becoming so if human cases of the disease are introduced. Further, there are places (Fiji and other Pacific Islands, New Zealand, etc.), at present without anopheles mosquitoes, which would seem to be capable of supporting them if once introduced. Within the last twelve months this has happened at Barbadoes, till then free from malaria and the anopheles. It was only when a sharp outbreak of fever proved to be malaria that it was found that the anopheles had at last colonised the island, arriving, in all probability, on ship-board.

The disease cycle runs man—mosquito—man, but for continued existence and multiplication of the mosquito, and therefore for the spread of the disease, water is a necessity. If Maps I and III are taken together it will be seen how closely the areas of indigenous malaria correspond with those of rainfall over 20 inches. The gravid female mosquito seeks water, in which to lay her eggs, with the same assiduity with which, after impregnation, she sought blood for their nourishment. In the water, in a few days, there emerge from the eggs the larvae often called " wrigglers " or " darters." These

feed at the surface of the water and breath air through a tiny pore by just breaking the surface film. They seek refuge when frightened, by swimming actively to the bottom in a series of quick, jerky movements. After some days of growth the larvae change into pupae, those curious comma-shaped creatures which neither feed nor grow but come to the surface to breathe air by means of two trumpet-like tubes upon their large heads. A few days more and from the pupa, whose case splits, there emerges the adult, winged insect, fully grown, to rest for a little on the floating pupa case and then to fly away on its aerial existence, as incapable of life in water as its immature stages are of life without it.

Water figures, in this story, only as the natural and necessary habitat of the egg, larva and pupa stages of the intermediate host, whereas in schistosomiasis certain stages of the disease parasite itself (miracidium and cercaria) are passed in water, as well as the whole life of the intermediary snail. In considering the relation of irrigation to malaria the whole problem (so far as transmission and spread is concerned) centres round the fact that the provision of additional water for agricultural purposes may mean the provision of additional places for the breeding and multiplication of anopheles mosquitoes, one of the chief factors in determining the intensity of malarial endemicity being the number of anopheles present to act as transmitters.

The additional breeding places may be in the large supply canals, although these are seldom dangerous unless neglected and allowed to have a growth of weeds and grasses along their margins or of duck-weed and the like upon their surface. The smaller branch channels are more favourable to mosquitoes and the final narrow ditches leading to the fields nearly always become sufficiently weed grown to form ideal breeding grounds. As a substitute for these dangerous channels the use of pipes deserves a fuller trial than it has yet received [Home, 1926.]. Breeding in the fields themselves is dealt with later. The drains taking off surplus present much the same problems as the supply channels. Underground drainage might perhaps be more employed than is the rule. Drying of the whole system periodically would be of value, and Keen (*loc. cit.*) indicates that agricultural interests would be unlikely to suffer, while in certain places of the Dutch East Indies, weekly drying of rice beds is compulsory [Darling, 1926.]; this should be made to include the smaller supply channels. Seepage from large canals whose water

level is above that of surrounding land is a not infrequent source of mosquito breeding and one difficult to deal with radically. Home (*loc. cit.*, pp. 68, 69) discusses this.

But the problem of malaria is not solely one of transmission. Difficult questions of human resistance to infection complicate the issue ; many of these are beyond the scope of this paper, but it may be mentioned that the immigration into a malarious district of persons not previously exposed to the disease and the aggregation of people in crowded conditions are two factors which of themselves tend to cause quiescent malaria to flare into an epidemic. Much attention has recently been given to a state of affairs called " anophelism without malaria," a condition in which anopheles continue to be present in abundance but malaria disappears. A good example of this is reported from France [Sergent, Chassaing and Fabiani, 1925.]. Roubaud believes that this condition is attributable to the anopheles having developed a preference for animal rather than human blood, a zoophily as it has been called [Roubaud, 1920–1925.]. Others [Sergent, *et al. loc. cit.*] [Langeron, 1922.] [Swellengrebel, 1925.] believe the disappearance of the malaria to be due to economic improvements as more fully explained below, and the balance of opinion seems to be against Roubaud. A review of the subject has been published in the *Journal of Parasitology*, with a good bibliography up to that date [Howard 1924.].

Malaria has died out in Scotland where it was once quite prevalent. Probably many factors were at work conjointly, but it is certain that to this day several efficient anopheles intermediaries are present with no lack of breeding grounds.

It may be accepted that irrigation schemes with their numerous canals and small channels will increase the number of potential breeding-places for anopheles and frequently cause an actual increase in the number of these mosquitoes. Until comparatively recent times it was thought that such an occurrence in a place where malaria was endemic must *infallibly* lead to intensification of the disease. Statistical enquiries into the question whether canal irrigation in India has or has not been followed by an increase of malaria have reached conflicting conclusions. The matter was discussed in a paper read at the Indian Science Congress at Lahore [Gill, 1927.]. Gill quotes S. M. Jacob (*Punjab Census Report*, 1921, p. 62) as having reached the conclusion that canal irrigation has not been followed by increased " fever " mortality. For long the prime methods of an

antimalaria campaign were the getting rid of open water, and the treating of waters not easily disposed of, by some larvicide or another. More often than not, to do this thoroughly is impossible, and it is is now being realized that effective *antimalaria* measures may be taken without any *antimosquito* measures being put into force, and among those effective measures there figures irrigation, none the less because it may leave unchanged, or may even increase, the number of anopheles in the area concerned. Such antimalaria measures include the schemes of " bonification " as practised chiefly in Italy. Drainage of land has often figured prominently in these schemes, and the misconception has grown up that this drainage was conceived and carried out as an anti-mosquito measure. This is not so, and in point of fact the drainage channels themselves have sometimes been more prolific in mosquito production than the swamps they drained. This side of the problem, with a clear indication of the anti-malaria possibilities of irrigation, is so well put in a recent publication [League of Nations, 1927] that some passages are quoted in full. The italics are not in the original.

> " We desire, in the first place, to refer to the problem of what should be done in certain regions where the conditions in which the people live and work are so primitive, and their economic position and social status and culture are so poor, that it is not possible in practice to apply direct measures in a manner which enables them to be brought to the standard which we call " minimal effective degree of perfection." In several European countries there are large or small areas in this class, and, like similar regions in the Tropics, they are very malarious. We are of opinion that, except the free distribution of quinine, no direct anti-malarial measure can be applied to them *until the land has been brought into such a condition that it is worth the while of the inhabitants to settle permanently upon it* and until those permanent settlers have reached a fair standard of housing and living.
>
> . . . . " *Agricultural reclamation of the land, so that people may be settled permanently upon it with a fair prospect of gaining a livelihood and perhaps a decent house and moderate comfort is, therefore, a measure which tends indirectly to produce a great reduction of malaria incidence and severity. In general, the better the agricultural reclamation is carried out from the point of view of increasing its productiveness, the quicker will malaria seem to disappear as an important cause of sickness and death—provided*

always, of course, that the people themselves share in the improved prosperity by being able to adopt a higher standard of housing and living. It is hardly necessary to say that when—as sometimes happens—reclaimed land is worked by hired labourers, who receive only a small fixed wage and live a life of great hardship in temporary huts and hovels, there is no improvement of malaria among them. Indeed, in the Tropics, highly cultivated areas where these conditions obtain continue to be among the most malarious in the world. *This proves that the actual measures necessary for reclamation* (*drainage, etc.*) *are not a factor which causes the health of the people to improve, but that the good result is due to the better conditions of living and housing which the increased productiveness of the soil enables the people to obtain.* The Netherlands is the country where the people as a whole have benefitted most from land reclamation, but, among the countries of Central and Eastern Europe, Italy is in the forefront as an exponent of schemes and systems of ' bonification ' as an anti-malarial and general sanitary measure.

" On a smaller scale, Palestine has recently provided some excellent examples of the benefits which have followed the general scheme of ' bonification ', which is gradually being applied as far as possible throughout the country. . . . The Italians . . . . do not regard the ' large bonifications ' as an anti-mosquito measure, and they know that such a bonification may increase the abundance of anopheles in the area reclaimed. But they also know that, in an area where bonification has been completed, and where in consequence the inhabitants settle permanently in better houses and in all the other circumstances of a moderately good standard of life, malaria tends more or less quickly to lose its importance as a cause of sickness and death. This good result more than compensates for an increase in the abundance of anopheles in the general environment. . . . When we utilise bonification we must do so as a whole ; our plan must include particularly the arrangements for raising the standard of life. . . The importance of these last items in the scheme is brought home to us by the knowledge that, when the inhabitants of reclaimed and highly cultivated land are not permitted themselves to reap the advantages of the increased productiveness of the soil, no improvement in malaria results. . . . .

" It should be added that all work of assainissement, drainage or construction of dams should be carried out under the control of a malariologist or of a health officer, who should have under his supervision all prophylactic measures. . . ."

Then follows an instructive note on a small " bonification " scheme observed by the Commission (p. 29).

" The locality was a dairy farm comprising 50 hectares of land near Simeto, on the plain of Catania. The situation was described to the Commission as being so malarious that it was uninhabitable. At the time of our visit, there was no village nearer to the estate than 20 kilometres. The proprietor commenced his project of bonification by building a road to the area, by bringing from 8 kilometres' distance the electric current which was required for lighting and power at the farm, and by constructing the necessary buildings, including a house for himself and houses for the staff and farm workers. *The land was gradually brought under cultivation, irrigation being used where required.* The slopes were planted with fruit trees, but the greater part of the land was used for growing lucerne and cereals. . . . By the end of the second year the malaria situation had ameliorated considerably, and it continued to do so year by year. At the end of six years the community comprised about 100 persons, and, according to the information given us, the amount of malaria among them was inappreciable.

. . . . " Many anopheles larvae were present in an irrigation canal near the buildings. We found no enlarged spleens among the few children whom we saw, and the people generally looked strong and well.

" The interest of this example is that no anti-larval or other methods of mosquito destruction were tried, and that both larvae and adult insects are still present in the area in quite sufficient numbers for malaria to spread ; the place is now an instance of ' anophelism without malaria.' "

One country differs from another so widely in the environmental conditions which favour the breeding of anopheles mosquitoes, and the habits and preferences of one species of anopheles are so distinct from those of another species that it is impossible to arrive at a more limited general statement of the effect of irrigation upon mosquito breeding than that already enunciated, namely that, *prima facie*, an increase of open-water channels likely to become grass grown provides increased opportunity for mosquito breeding. The irrigated fields

themselves are less dangerous. But when it is realized that some anopheles prefer still, clear, shaded pools, some fast-running streams exposed to full sunshine, others again brackish, tidal marshes, and that many, if their favourite circumstances are not available can accommodate themselves to other conditions [Swellengrebel, 1919] it is not to be wondered at that the literature of malaria contains little that is clear-cut, or definite, or generally applicable, upon the influence of irrigation upon malaria prevalence.

One publication, however, requires special notice, Bentley's *Malaria and Agriculture in Bengal. How to Reduce Malaria in Bengal by Irrigation* [Bentley, 1925.]. Its title commands attention and the position and experience of its author, who is Director of Public Health, Bengal, give the work the stamp of authority. In considering Bentley's views it must be remembered that in Bengal it is mainly in the wet season that breeding of anopheles mosquitoes is plentiful and malaria widespread and serious, and that 90 per cent. of cultivated land is occupied by wet crops, rice and jute. Briefly, Bentley's argument is that the embankment of rivers, preventing their flooding the land, and the drainage schemes which have been carried out, have not reduced mosquito breeding (and so malaria) because, in the wet season, there are innumerable low-lying places, marshes, and the like, which are unaffected by the procedures mentioned, and continue to hold water and breed mosquitoes. In his view, the case of Bengal can best be met by reverting to what he calls the natural flood and flush system of irrigation, by which the natural overflow of the rivers, aided by devices such as weirs, will perform an annual irrigation essentially similar to the basin irrigation of Egypt. The underlying anti-mosquito principle of this recommendation is that large areas of water are much less dangerous as mosquito breeding grounds than are small pools and swamps, and Bentley's plan would convert the small water collections into large ones at the time when small ones would be most dangerous. Several factors undoubtedly make large inundations less dangerous than small pools ; for example, the amount of mosquito breeding is proportional not to the area of water surface, but to the length of water edge, and large water collections more easily reach a temperature inimical to mosquito breeding than do small weed-sheltered pools and ditches.

The Professor of Medical Entomology at Calcutta has published a critical review of Bentley's work [Strickland, 1925.] in which he expresses reserve as to the likelihood of Bentley's proposals effecting

a reduction of malaria, or of mosquitoes, but supports the recommendations on the ground that an irrigation scheme " must necessarily have an economic value so that not much would be lost if it failed from a health point of view." He seems to overlook the possibility of success from the health point of view *because* of the economic improvement, even although his doubts as to mosquito reduction should be justified in the outcome. Indeed, Strickland seems to have misunderstood the essence of the Italian anti-malarial work by economic improvement, for he follows the remark quoted above by saying : " And the proceeds might, following the very good Italian custom, be earmarked for later and better anti-malarial schemes."

In Italy, the Lake of Lentini, (an artificial formation dating from 700 years ago), has been neglected and, becoming weed-grown, is both a source of malaria in its neighbourhood and an intolerable nuisance from the smell of decaying weed. Rival schemes have been put forward, some recommending complete filling, others drainage ; and there is a third proposal [Grassi, 1925.] indicative of the trend of modern opinion by an observer who favours filling rather than drainage, but in this case he finally decides that " the only project worth serious consideration is to transform it (the lake) into a reservoir for irrigation, since this would lead to intense cultivation, and thereby to eradication of malaria and improvement of the people in health and wealth."

A good deal has been written about inundated rice fields as a source of anopheles breeding and consequent malaria. The gist of the matter seems to be that, in most countries (perhaps in all) fields of growing rice, in which the water remains stagnant, are not seriously to be feared, but that the small grass-grown channels conveying the water to the fields are very dangerous, and fields in which the water is circulating all the time may become so. Observations from various countries are available : rice fields in India—" Very exceptionally dangerous, but may be so when the water is in continuous motion through the fields " [Knowles and Senior-White, 1927.]. In Indo-China, in the rice fields of the terraced hillsides where water flows from one level to another, anopheles abound ; in the deltas, where water once applied to the fields is not changed, anopheles are scarce or absent [Kerandel, 1925.]. In British Guiana [Bodkin, 1925.] no anopheles were found in experimental, stagnant rice fields but abundant larvae in the small grass-grown irrigation ditches : " All

over the colony you find very few larvae in rice fields themselves, but rather in the irrigation schemes." In Madagascar the rice fields, where the water is stagnant, are a source of little or no breeding [Couvy, 1925.]. The causes of this difference between stagnant and moving water in fields of growing rice are difficult to determine. Couvy (*loc. cit.*) gives some discussion of the matter. It would seem, however, that the rice plants have something to do with it, for several writers record that rice fields allowed to remain flooded after the crop has been gathered, or lying fallow, are specially dangerous as prolific breeding-grounds [Senior-White, 1926.] [Darling, 1926.] [Mangoewinoto, 1923.].

In irrigated sugar fields, however, the shaded channels between the rows of cane sometimes provide a prolific breeding ground.

It is a feature of many irrigation schemes that by damming a river or impounding smaller streams, a great reservoir is created from which water is distributed in accordance with what is available and what is required. Mosquito breeding in impounded waters has lately received special study in America and though many of the reservoirs which have been observed have been constructed for hydro-electric schemes, the knowledge elucidated is applicable to waters stored for irrigation. The edges of these artificial lakes, the places of entry of creeks and collections of drift material are the sites chosen by anopheles for egg deposition, and the filling of such reservoirs has been associated with sharp outbreaks of malaria. A very full study of a typical epidemic arising from this cause has been published in America [Smillie, 1927.], and the outcome of American experience has been well summarized as follows [Le Prince, 1927.] :—

> " To prevent production of anopheles in lakes : (*a*) When practical hold the water about 2 feet or more higher in the non-mosquito season than in summer. Use flashboards, gates or other regulating devices for water level control purposes. The object of lowering the water level is to strand floatage along the shore line, to bring any mosquito larvae present away from vegetation protection and leave them at a clean shore edge where their enemies can get them. Also to make the shore line unattractive to mosquitoes. (*b*) Keep the water surface free of floatage. (*c*) When new aquatic plants appear, remove the first that come up. Cat-tails and some other plants multiply rapidly, and are expensive to remove if given a good start.

(*d*) In clearing brush, trees, etc., from the lake bed, make a good clean job of clearing in the upper third of all lake inlets. Wave protected inlets may become important breeding places of malaria-conveying mosquitoes. (*e*) As mosquito production is generally at its maximum during the first three years after the water is impounded, weekly inspection of the lake may then be necessary. (*f*) In some instances collection and removal of floatage may be facilitated by using booms made of logs or saplings. (*g*) It is decidedly advisable to start fish hatcheries (for mosquito-destroying fish) several years before water is impounded. It is not possible to overstock the lake with mosquito-destroying fish. (*h*) To destroy mosquito larvae we apply oil or larvacides."

Detailed studies of the effect of altering the water level are available [Carter, 1924] ; [*Amer. J. Pub. Health,* 1926.] and an American writer has described the abolition of breeding places in a reservoir by the creation of wave action by the daily cruising of a motor boat [Kibbey, 1925.].

Malaria has so often been a bane during constructional works, such as those of an irrigation project, that reference must be made to the factors concerned. It is hardly necessary to recall that malaria played a major part in bringing to naught the French plans for the Panama Canal. Long before knowledge of malaria had made any real progress, it was observed that engineering works involving considerable opening up of the soil were frequently accompanied by serious, even disastrous, outbreaks of disease. Later this was found to be malaria, and it became customary to explain these epidemics by pointing to the many water-filled hollows created by the work, the belief being that the multiplying of anopheles in these pools was responsible for the prevalent malaria. The following passage [Christophers, 1908.] sums up the position :—

" In reality this is quite an inadequate conception of the true state of affairs. Operations for ' opening up the soil ' involve certain conditions. The most important is the formation of enormous camps of coolie labourers and their families, drawn from far and wide throughout the district, or even from distant countries. In such camps, of far more importance than extra facilities for the breeding of anophelines, are such conditions as the mixture of races and classes involving aggregation of susceptibles with infected ; the depressing effects of

hardship, especially affecting the weaker, who in turn, by becoming malarial disseminators take their part in the vicious cycle ; crowding of the population into communities larger than occur in ordinary rural conditions, but not large enough to obtain the benefits of urban conditions ; and many other factors which need not be specified. Naturally the Europeans and others employed in supervision suffer in the general trouble, since, in their ignorance they dwell in the midst of the natives. The belief that malaria comes from the opening up of the soil is, therefore, based upon fact, but the responsibility is not with the miasmatic exhalations nor even with the extra facilities for the breeding of anophelines ; it is bound up in the general conditions inseparable from the existence of great labour camps in the tropics."

These words have been quoted in *Malaria at Home and Abroad* [James, 1920.], a publication which persons non-medical, but none the less confronted by malaria as a problem of their daily work, will find most helpful. Of the ten chapters only three and a part of a fourth deal with matters mainly outside the sphere of engineers whose work brings them into conflict with malaria, and the whole problem is discussed with unusual clarity.

A recent and good example of the arrangements for disease prevention on a big irrigation project is available in the work at Sennar during the construction of the dam and canals for the newest Sudan irrigation scheme. It is described in an unsigned article [*Brit. Med. J.*, 1926.]. Some extracts are reproduced here from a summary of that article made by the present writer for the *Bulletin of Hygiene.*

" The undertaking culminated in the opening of the Sennar Dam and the irrigation of 300,000 acres of land. The work took five years to complete, and the control of disease (notably of malaria) was progressive. At the dam itself the problem was the prevention, in a place naturally malarious, of widespread malaria among many thousands of labourers.

" Incoming labour (from Egypt) was quarantined at Wady-Halfa, where the unfit were rejected.*

" The Sudanese possessed some degree of natural immunity (to malaria) and were segregated from the more susceptible Egyptian labourers. Dwellings were screened, and a British

* For a full account of the quarantine, see Spence, *J. Roy. Army Med. Corps*, 1924, v. 43, pp. 321–40.

Medical Inspector and Sanitary Inspector were placed in charge of the preventive work, while hospital accommodation and first-aid stations were provided and staffed.

" The high land on which houses and workshops were built was drained and grass and bushes were cleared for 100 metres. Later, the marsh itself was drained . . . . and holes were filled. The deep drains through the marsh to the river were protected by sluices and pumping was resorted to when the height of the Nile demanded this, while the riverbank was raised by an embankment for a length of three kilometres.

" The control of malaria in the irrigated area was more difficult, for though this part is not naturally malarious, the nature of the works made ample opportunity for mosquito breeding, and regular inspection of many gangs of labourers scattered over a wide territory was difficult. Prophylactic quinine was only employed where it was essential for work to be carried out in malarious places or when circumstances did not warrant extensive preventive works. It was found to be helpful."

The original contains tables which demonstrate the success of the sanitary measures, and mentions a temporary breakdown of these when the rains and the network of canals combined to make inspection and control almost impossible.

If the foregoing notes on malaria have left any clear impression at all, it will probably be that it is impossible to formulate any definite, comprehensive statement of the relationship between malaria and irrigation, upon which a generally applicable practical policy can be based, and such is the case. The Malaria Commission of the League of Nations Health Organization recently made a special study on a big scale in Palestine, in which they successfully controlled malaria. But Swellengrebel, a member of the Commission and a noted malariologist, admits that, on account of the ample funds, the work had the character of a vast scientific experiment rather than of a practical campaign on economic lines, while the knowledge gained was of limited application elsewhere, since open concrete ditches, safe in Palestine, would breed *Anopheles maculatus* in Sumatra ; the simple apparatus and personnel effective in Jerusalem would be useless in Bombay ; and certain populations will tolerate and maintain conditions impossible of attainment among other peoples [Swellengrebel, 1925.].

Without doubt the golden rule is that no irrigation scheme should be carried out in a malarious or potentially malarious country without the most careful preliminary survey by, and continuous guidance and co-operation of, an experienced malariologist, properly staffed and equipped.

In conclusion, it is instructive to regard Map I with its white and blue areas of rainfall under 20 inches as a map of the areas where irrigation schemes are likely to be proposed, and in turn to superimpose on that map the tracings* from Maps II and III, which show the distribution of schistosomiasis and malaria respectively. This will demonstrate convincingly that nearly everywhere that an irrigation project is likely, one or other or both of these diseases, both closely associated with water channels, is waiting on the threshold.

Within the last few weeks the daily press has announced the framing of great irrigation schemes for Northern Africa. The barren area proposed for cultivation has all along its northern boundary endemic malaria and schistosomiasis, and the latter is present in the oases dotted over this desert. In a report received on 17.9.28 [Morrison, 1927.], one reads : " Irrigation schemes for the arid places in the Northern Provinces [Nigeria] will, most probably, be approved in the near future. If this happens, it is more than likely that a local increase in the incidence of bilharziasis will result." Morrison's observations are not without significance in view of the numerous places from which cases of schistosomiasis have been reported, but in which the intermediary snail has not been found. His laboratory examinations at Kaduna make it plain that schistosomiasis is endemic, but hitherto his searches in small streams have revealed no trace of any mollusc. This point is further elaborated in an Appendix (I) to this report.

* The tracings are in the pocket inside the back cover.

REFERENCES.

Amer. J. Pub. Health, 1926, v. 16, 258–262. Report of Commission on Mosquito Control.

BALFOUR, A. & SCOTT, H. H. (1924). *Health Problems of the Empire*, p. 222, London, 1924, W. Collins & Sons.

BENTLEY, C. A. (1925). *Malaria and Agriculture in Bengal. How to Reduce Malaria in Bengal by Irrigation*, Calcutta, 1925, Bengal Secretariat Book Dept.

BODKIN, G. E. (1921). Experiences Regarding Malarial Transmission in British Guiana. *Rep. of Proc. of West Ind. Med. Conference*, 1921, pp. 118–123, Georgetown, Demerara, 1921, The Argosy Coy.

Brit. Med. J., 1926 (1), 109–111. The Construction of the Sennar Dam, Sudan. Antimalarial Organization.

CAMERON, T. W. M. (1928). A New Definitive Host for *Schistosoma mansoni*. *J. Helminthol*, 1928 v. 6, 219–222.

CARRIER, E. H. (1928). *The Thirsty Earth*; *A Study in Irrigation*, London, 1928, Christopher.

CARTER, H. R. (1924). The Effect of Variation of Level of Impounded Water on the Control of Anopheles Production. *Southern Med. J.*, 1924, v. 17, 575–578.

CAWSTON, F. G. (1925). Bilharzia Infection at the Source of our Rivers. (Correspondence). *Med. J. of S. Africa*, 1925, v. 21, 58.

CAWSTON, F. G. (1926). Environmental Influences which Favour the Development and Spread of the Bilharzia Parasite in South Africa. Food Supply of "Physopsis." *J. Trop. Med. & Hyg.*, 1926, v. 29, 89–91.

CAWSTON, F. G. (1928). The Control of Bilharzia Disease. *Kenya & E. African Med. J.*, 1928, v. 5, 110–111.

CHRISTOPHERS, S. R. (1908). *Scientific Memoirs by Medical Officers of the Government of India, New Series, No.* 35, 1908, p. 21. Quoted in *Malaria at Home and Abroad*, see JAMES, S. P. (1920), p. 17.

COUVY, (1925). Le fonctionnement du service de défense contre le paludisme à Madagascar, 1923–1924. *Ann. de Méd. et de Pharm. Colon.*, 1925, v. 23, 238–264.

DARLING, S. T. (1926). Mosquito Species Control of Malaria. *Amer. J. Trop. Med.*, 1926, v. 6, 167–178.

GALTIE, (1913). *Bull. Economique de Madagascar*, 1913. Quoted by COUVY (1913), *q.v.*

GILL, C. A. (1927). *The Relationship of Canal Irrigation and Malaria.* Mimeographed copy of paper read at Indian Science Congress, Lahore, 1927. (Lent by Committee of Civil Research.)

GRASSI, B. (1925). *Bonifiche, laghi artificiali e malaria, a proposito del lago di Lentini*, 1925, Rome. Abstracted by H. H. SCOTT in *Bulletin of Hygiene*, 1927, v. 2, 592.

GRIESINGER, W. (1854). Klinische und anatomische Beobachtungen über die Krankheiten von Aegypten. *Arch. für Physiol. Heilk. Stuttg.*, 1854, v. 13, 528–575. Quoted at p. 3 by KHALIL (1924a), *q.v.*

HOME, H. (1926). *The Engineer and the Prevention of Malaria*, London, 1926, Chapman & Hall, Ltd.

HOUGHTON, H. S. (1920). Schistosomiasis of the Far East. *The Practice of Medicine in the Tropics*, v. 3, 1773–1788, edited by Byam & Archibald, London, 1920, Oxford Med. Publications.

HOWARD, L. O. (1924). On Zoophilism with Anopheles—A Review. *J. Parasitol.*, 1924, v. 10, 191–198.

IBRAHIM, ALI BEY (1927). The Problem of Bilharziasis in Egypt. *J. State Med.*, 1927, v. 35, 702.

JAMES, S. P. (1920). *Malaria at Home and Abroad*, London, 1920, Bale Sons & Danielsson.

KEEN, B. A. (1927). *Memorandum on Irrigation Practice and Proposals*, London, 1927, The Empire Marketing Board.

KERANDEL, J. (1925). Riziculture et distribution géographique de paludisme en Indochine. Insectes prédateurs de larves de moustiques. *Bull. Soc. Path. Exot.*, 1925, v. 18, 815–821.

KHALIL, M. A. (1924a). *Reports and Notes of the Public Health Laboratories, Cairo, No.* 6, p. 112, Cairo, 1924, The Government Printer.

KHALIL, M. A. (1924b). *Ibidem*, 103–157.

KHALIL, M. A. (1926). The Bearing of Agricultural Schemes in the Nile Valley on Bilharziasis as observed at Kom Ombo Company Estate. *J. State Med.*, 1926, v. 34, 472–477.

KHALIL, M. A. (1927). The Eradication of Bilharziasis : A Successful Attempt in an Endemic Area. *Lancet*, 1927 (2), 1235.

KIBBEY, C. H. (1924). Larvicides. Trans. 5th Conference of Malaria Field Workers, New Orleans, 1924. *Pub. Health Bulletin, No.* 156, 141–142, Washington, 1925, Treasury Dept., U.S.A.

KNOWLES, R. and SENIOR-WHITE, R. (1927). *Malaria, Its Investigation and Control*, Calcutta, 1927, Thacker, Spink & Co.

LANGERON, M. (1922). Sur l'anophéline et le paludisme en France. *Bull. Soc. Path. Exot.*, 1922, v. 15, 30–36.

LEAGUE OF NATIONS (1927). Malaria Commission, 2nd General Report, *The Principles and Methods of Antimalarial Measures in Europe*, p. 27, *et. seq.*, Geneva, 1927.

LEIPER, R. T. (1918). *Researches on Egyptian Bilharzioses*, London, 1918, Bale Sons & Danielsson, reprinted from *J. Royal Army Med. Corps*, 1915, 1916, 1918.

LE PRINCE, J. A. (1927). Mosquito Control in Relation to Impounded Water Supply. *J. Amer. Water Works Assoc.*, 1927, v. 17, 31–36.

MANGOEWINOTO, R. M. M. (1923). Sanitation of the Tijihea-Plain. *Meded. Burgerlijk. Geneesk. Dienst Ned.-Indie*, 1923, Part 3, 236–274, abstracted by W. W. CLEMESHA in *Trop. Dis. Bull. San. Supp.*, 1924, p. 87.

MORRISON, H. (1927). *Nigeria Ann. Med. & San. Rep. for* 1927, p. 85.

ROUBAUD, E. (1920–1925). Les conditions de nutrition des anophèles en France (*Anopheles maculipennis*) et le rôle du bétail dans la prophylaxie du paludisme. *Ann. Inst. Pasteur*, 1920, v. 34, 181–228.

La differenciation des races zootropiques d'anophèles et la régression spontanée du paludisme. *Bull. Soc. Path. Exot.*, 1921, v. 14, 577–595.

A propos des races zoophiles d'anophèles. *Ibidem*, 1922, v. 15, 36–39.

Peuplements humains et peuplements animaux comme facteurs économiques comparés de la déviation anophélienne antipalustre. *Ibidem*, 1925, v. 18, 728–730.

SENIOR-WHITE, R. (1926). Physical Factors in Mosquito Ecology. *Bull. Entomol. Res.*, 1926, v. 16, 187–248.

SERGENT, ET., CHASSAING, J. & FABIANI, G. (1925). Assainissement naturel d'une localité de la Haute Auvergne (Minet). *Arch. Inst. Past. d'Algérie*, 1925, v. 3, 127–131.

SMILLIE, W. G. (1927). Studies of an Epidemic of Malaria at the Gantt Impounded Area, Covington County, Alabama. *Amer. J. Hyg.*, 1927, v. 7, 40–72.

SPENCE, B. H. H. (1924). The Wadi Halfa Quarantine. *J. Roy. Army Med. Corps*, 1924, v. 43, 321–340.

SPENCE, B. H. H. (1925). The Eradication of Helminthiasis from the Egyptian Army. *J. Roy. Army Med. Corps*, 1925, v. 44, 321–342.

STRICKLAND, C. (1925). A Critical Review of Dr. C. A. Bentley's "Malaria and Irrigation in Bengal." *Ind. Med. Gaz.*, 1925, v. 60, 588–590.

SWELLENGREBEL, N. H. (1919). On the Requirements of Different Anophelines in Regard of the Abode of their Larvae. *Meded. Burgerlijk. Geneesk. Dienst Ned.-Indie*, 1919, Part 7, 17, cited by KNOWLES & SENIOR-WHITE in *Malaria. Its Investigation & Control*, Calcutta, 1927, Thacker, Spink & Co.

SWELLENGREBEL, N. H. (1924). Considerations sur la prophylaxie du paludisme par la déviation des anophèles. *Bull. Soc. Path. Exot.*, 1925, v. 18, 725–727.

SWELLENGREBEL, N. H. (1925). *Reports on the Tour of Investigation in Palestine in 1925*, Geneva, 1925, League of Nations Malaria Commission.

APPENDIX I.

GEOGRAPHICAL BIBLIOGRAPHY OF REPORTED CASES OF SCHISTOSOMIASIS.

It seems doubtful whether the wide geographical distribution of schistosomiasis is appreciated. Further, clinical cases have been and are being reported from many places in which the intermediary snails have not yet been recorded, and it is very questionable whether all of these can be written off as non-indigenous. In many of the places where these cases occur, conditions seem to be very suitable for the life of the snails and there are localities where undoubtedly indigenous schistosomiasis is occuring, but where search has not yet revealed the mollusc.

The means of spread of the snails from one place to another is not well understood, but if Khalil is correct in his statement as to carriage in immature form by birds (see p. 15) then even countries definitely without the snails would appear to be in danger of colonization, more especially if large irrigation schemes provide, as it were, a series of stepping-stones across what is now barren desert; for example, the colonization of India (if, indeed, India is at present free), by the snails known to be present in Mesopotamia, would seem to be a possibility.

It may, therefore, be useful to have a full bibliography of reported cases of schistosomiasis, geographically arranged. It is thought that from the following list few places where cases have been found have been omitted, though no pretence is made to absolute completeness in respect of individual papers. Indeed, to avoid swelling the list to undue proportions, many references to schistosomiasis in Egypt have been deliberately omitted; those given for that country cover the early records of the disease and the most recent. The list has been complied from the key map and bibliography in Professor Leiper's monograph on *Egyptian Bilharzioses* and from the records of the Bureau of Hygiene & Tropical Diseases.

SCHISTOSOMIASIS.

EUROPE.

Bulgaria.

Dimitracoff, C. *Bull. et Mém. Soc. Méd. des Hôpit. de Paris*, 1925, v. 48, 1771–4.

Crete.

Milton, F. *Lancet*, 1920, Jan. 24, 196–7.

Corsica.

Brumpt, E. & Werblunsky, S. *Bull. Acad. Méd.*, 1928, v. 99, 153–5.

Cyprus.

Williamson, G. A. *Brit. Med. Jl.*, 1902, Sept. 27, 956.
——. *ibid.*, 1907, Nov. 9, 1333.

England.

Faichnie, N. *J. Roy. Army Med. Corps*, 1905, v. 5, 638–39.
Freeman, E. C. *J. Roy. Army Med. Corps*, 1907, v. 8, 278–79.

GERMANY.

PODGUN, B. *Arch. f. Schiffs- u. Trop.-Hyg.*, 1928, v. 30, 35.

ITALY.

GABBI, U. *Malaria e Malat. d. Paesi Caldi*, 1916, v. 7, 301–304.

PORTUGAL.

BETTENCOURT, A. & BORGES, I. *Bull. Soc. Path. Exot.*, 1927, v. 20, 350–64.
BETTENCOURT, A., BORGES, I. & DE SEABRA, A. *C.R. Soc. Biol.*, 1922, v. 86, 330–31.
BETTENCOURT, A. & FIGUEIRA, L. *C.R. Soc. Biol.*, 1923, v. 88, 319–20.
BORGES, I. *Bull. Soc. Portugaise des Sci. Naturelles*, 1921, v. 9 (reprint).
CHARRIER, H. *Bull. Soc. Path. Exot.*, 1923, v. 16, 491–4.
FRANÇA, CARLOS. *Bul. Soc. Portugaise des Sci. Naturelles*, 1925, v. 10, 63–77.
FRANÇA, C. & DE MELLO, F. *Med. Contemporanea*, 1921, v. 39, 273–5, 281–4.

ASIA.

ARABIA.

GREVAL, S. D. S. *Indian Jl. Med. Res.*, 1923, v. 10, 943–7.
SANDWITH, F. M. In *System of Med.* (Allbutt & Rolleston), 1909, v. 2, 864–83.
MANSON, P. *Trop. Dis. Manual*, 1903, 605–606, 639, Cassell & Co., Ltd.

BURMA.

CROSTHWAITE, W. S. *J. Roy. Army Med. Corps*, 1908, v. 9, 524–5.
ATKINSON, E. L. *Jl. Roy. Nav. Med. Serv.*, 1916, v. 2, 485–90.

CHINA.

FAUST, E. C. & MELENEY, H. E., *Amer. J. Hyg.*, Monograph Ser., 1924, No. 3.
——— —. *Lancet*, 1924, Jan. 5, 21–24.
——— —. *Proc. Roy. Soc. Med.* (Sect. Trop. Dis. & Parasit.), 1924, v. 17, 31–42.
FAUST, E. C. *Arch. Path. & Lab. Med.*, 1926, v. 2, 223–40.
LANNING, R. H. *U.S. Naval Med. Bull.*, 1914, v. 8, 16–36.
LEE, C. U. *China Med. J.*, 1925, v. 39, 321–31.
MANN, W. L. *J. Amer. Med. Assoc.*, 1916, v. 67, 1366–1368.
MAXWELL, J. L. *J. Trop. Med. & Hyg.*, 1916, v. 19, 237–8.
MELENEY, H. E. *U.S. Naval Med. Bull.*, 1924, v. 21, 630–6.
MELENEY, H. E. & FAUST, E. C. *China Med. J.*, 1923, v. 37, 541–54.
NAUCK, E. G. & SHAN YU. *Arch. f. Schiffs- u. Trop. Hyg.*, 1926, v. 30, 503–510.
REED, A. C. *Amer. J. Trop. Dis. & Prevent. Med.*, 1915, v. 3, 250–73.
TAI, J. T. *Nat. Med. J. China.*, 1924, v. 10, 370–76.

FRENCH INDO-CHINA.

ADVIER, *Ann. Méd. et Pharm. Colon.*, 1926, v. 24, 571–8.

FORMOSA.

SUEMORI, S. *Ni. Byor. Gak. K.*, 1921, v. 11, 458–9 (summarized in *Japan Jl. Med. Sciences*, 1922, v. 1, 63).

India.

Cullen, J. P. *Brit. Med. Jl.*, 1925, Apr. 11, 694.
——. *J. Trop. Med. & Hyg.*, 1924, v. 27, 337–8.
Hatch, W. K. *Brit. Med. Jl.*, 1903, v. 1, 772.
Kay, J. A. *Transvaal Med. Jl.*, 1913, v. 8, 199–205.
Kemp, S. *Indian Jl. Med. Res.*, 1919, v. 7, 251–64.
McLeod, K. *Indian Med. Gaz.*, 1903, v. 38, 225.
Montgomery, R. E. *Jl. Trop. Vet. Sci.*, 1906, v. 1, 15–46.
Powell, A. *Brit. Med. Jl.*, 1903, Feb. 28, 490.
Sewell, E. P. *Jl. Roy. Army Med. Corps*, 1904, v. 2, 346–7.
Soparkar, M. B. *Indian Jl. Med. Res.* (Spec. Indian Sci. Congress Number 1919), 207–213.

Japan.

Faust, E. C. & Meleney, H. E. *Amer. Jl. Hyg.*, Monograph Ser., 1924, No. 3.
Koiki, G. *Saikin Gaku Zasshi*, 1916, No. 246, 523–30.
Odaka, Y., Murata, S. & Nagao, S. *Iji Shimban* (Med. News), 1926 (summarized in *Japan Med. World*, 1926, v. 6, 350).
Reed, A. C. *Amer. Jl. Trop. Dis. & Prevent. Med.*, 1915, v. 3, 250–73.

Java.

Mengert-Presser, H. *Meded. Burgerlijk. Geneesk. Dienst in Nederl.-Indië*, 1923, Part 3, 227–35.

Korea.

Ludlow, A. J. *China Med. Jl.*, 1924, v. 38, 829–32.

Mesopotamia.

Boulenger, C. L. *Indian Jl. Med. Res.*, 1919, v. 7, 8–21.
Hall, A. H. *Jl. Roy. Army Med. Corps.*, 1925, v. 44, 1–10, 92–102.
Sturrock, P. S. *Brit. Med. Jl.*, 1899, Dec. 2, 543.

Palestine.

Buxton, P. A. & Krikorian, K. S. *Trans. Roy. Soc. Trop. Med. & Hyg.*, 1922, v. 16, 162–66.
Felix, A. *Amer. Jl. Trop. Med.*, 1925, v. 5, 41–61.
Malchi, A. *Harefuah* (Palestine Hebrew Med. Jl.), 1924, v. 1, 75–9.
Searle, C. *Jl. Roy. Army Med. Corps*, 1920, v. 34, 15–34.

Persia.

Scott, J. *Brit. Med. Jl.*, 1904, (1), 725.

Philippine Islands.

Mendoza-Guazon, M. P. *Philippine Jl. Sci.*, 1922, v. 21, 535–67.
——. *Jl. Philippine Islands Med. Assoc.*, 1922, v. 2, 1–6.
Reed, A. C. *Amer. Jl. Trop. Dis. & Prevent. Med.*, 1915, v. 3, 250–73.

Sinai Peninsular.

O'Connor, F. W. *Jl. Trop. Med. & Hyg.*, 1919, v. 22, 166–7.

Syria.

Manson, P. *Trop. Dis. Manual*, 1903, 605–606, 639, Cassell & Co.
Pomme & Abdel-Kader-Sabbach. *Arch. Méd. et Pharm. Milit.*, 1923, v. 78, 290–3.
Pomme & Sabagh, A-K. *Bull. Soc. Path. Exot.*, 1922, v. 15, 695–8.

AFRICA.

ABYSSINIA.

SANDWITH, F. M. In *System of Med.* (Allbutt & Rolleston), 1909, v. 2, 864–83.

ALGERIA.

LEGRAIN, E. *Arch. de Parasitol.*, 1898, v. 1, 148–51.
REYNAUD, L. *Bull. Office Internat. d'Hyg. Pub.*, 1926, v. 18, 1409–12.

BELGIAN CONGO.

BERTRAND. *Bull. Méd. de Katanga*, 1924, v. 1, 154–5.
BRODEN, A. *Ann. Soc. Belge de Méd. Trop.*, 1921, v. 1, 171–3.
——. *Ann. Soc. Belge de Méd. Trop.*, 1922, v. 2, 131–2.
DUPUY, L. *Ann. Soc. Belge de Méd. Trop.*, 1925, v. 5, 37–9.
FIRKET, C. *Bull. Acad. Roy. Belge*, 1897, June.
LAGRANGE, E. *Bull. Soc. Path. Exot.*, 1920, v. 15, 28–9.
MERSCH. *Ann. Soc. Belge de Méd. Trop.*, 1926, v. 5, 197–9.

BRITISH W. AFRICA (see also individual territories by name).

EYRES, C. H. *Lancet*, 1887 (2), 659–60.
Report of the Lagos Medical Research Institute for the Year 1916.

CAMEROONS.

SANDWITH, F. M. In *System of Med.* (Allbutt & Rolleston), 1909, v. 2, 864–83.

CENTRAL AFRICA.

DYE, W. H. *Jl. Roy. Army Med. Corps*, 1924, v. 43, 161–81.

EAST AFRICA (see also individual territories by name).

East Africa Protectorate Ann. Med. Rep. for the Year ending 31st Dec., 1914, 20–21.
LAGRANGE, E. *Bull. Soc. Path. Exot*, 1920, v. 13, 28–29.
SHIRCORE, J. O. *Parasitology*, 1916, v. 8, 239–43.
——. *Trans. Soc. Trop. Med. & Hyg.*, 1917, v. 10, 101–108.

EGYPT.

IBRAHIM, ALI BEY. *Jl. State Med.*, 1927, v. 35, 702–708.
BILHARZ, T. *Zeit. d. k-k. Ges. d. Aertze zu Wien.*, 1858, v. 14, 447.
COBBOLD, T. S. *Lancet*, 1882 (1), 272.
DAY, H. B. *Lancet*, 1911 (2), 1328–32.
ELGOOD, B. S. *Brit. Med. Jl.*, 1908, Oct. 31, 1355.
FERGUSON, A. R. *Jl. Roy. Army Med. Corps*, 1917, v. 29, 57–65.
HUGHES, G. W. G. *Lancet*, 1911 (2), 880–81.
KHALIL, M. *Reps. & Notes, Pub. Health Lab., Cairo*, 1924, No. 6, 183–5, 159–82.
——. *Jl. Helminthol.*, 1926, v. 4, 115–22.
KAY, J. A. *Transvaal Med. Jl.*, 1913, v. 8, 199–205.
LOOSS, A. *Recherches sur la Faune parasitaire de l'Egypt*, 1896, Part 1, Inst. Egypt, 2, 64 and 158–66.
——. *Brit. Med. Jl.*, 1909, March 27, 773–77.
——. *Jl. Trop. Med. & Hyg.*, 1911, v. 14, 177–82.
MADDEN, F. C. *Practitioner*, 1899, v. 62, 566–68.
——. *Brit. Med. Jl.*, 1910 (2), 965.
MILTON, F. *St. Thomas's Hosp. Rep.*, 1897, 93.
RUFFER, M. A. *Brit. Med. Jl.*, 1910, Jan. 1, 16.

SANDWITH, F. M. *Med. Diseases of Egypt*, 1905, 214.
SHATTOCK, S. G. *Trans. Path. Soc.*, 1891, v. 42, 196.
——. *Trans. Path. Soc.*, 1905, v. 56, 275–90.
SONSINO, P. *Baltimore Phys. & Surg.*, 1875, v. 3, 9–10.
——. *Arch. Gén. de Méd.*, 1876, June, 652–673.
——. *C.R. Congrès Internat. Sci. Méd.*, 1877, v. 3, 651–3.
——. *Veterinarian*, 1882, v. 55, 569–73.
WALKER, J. H. C. *Jl. Roy. Army Med. Corps*, 1925, v. 44, 382–4.

FRENCH EQUATORIAL AFRICA.
CLAPIER, P. *Bull. Soc. Path. Exot.*, 1923, v. 16, 559–64.
——. *Bull. Soc. Path. Exot.*, 1920, v. 13, 804–809.
LEFROU, G. *Rev. Méd. de Angola*, 1923, Aug., No. 4, 135–9.
LETULLE, M. *Bull. Soc. Path. Exot.*, 1908, v. 1, 280–4.

FRENCH WEST AFRICA. (See also SENEGAL.)
BOUET & ROUBAUD. *Bull. Soc. Path. Exot.*, 1912, v. 5, 837–42.
BOUFFARD & NEVEUX. *Bull. Soc. Path. Exot.*, 1908, v. 1, 430–2.
CLAPIER. *Ann. de Méd. et de Pharm. Colon.*, 1926, v. 24, 56–67.
DURAND, P. *Arch. Inst. Pasteur de Tunis*, 1928, v. 15, 348–61.
EMILY, *Ann. de Méd. et de Pharm. Colon.*, 1926, v. 24, 370–83.
JOYEUX, CH., *Bull. Soc. Path. Exot.*, 1912, v. 5, 504–505.
LEGER, M. *Revista Méd. de Angola.*, 1923, No. 4, 141–8.
NEVEU-LEMAIRE, M. & ROTON, A. *Arch. de Parasitol.*, 1912, v. 15, 474–77.
PEYROT, J. *Ann. Hyg. Méd. Colon.*, 1905, 105–111.

GOLD COAST.
Gold Coast Med. & San. Rep. for the Year 1915.
HUPPENBAUER, K. *Arch. f. Schiffs- u. Trop.-Hyg.*, 1918, v. 22, 341-64.
MACFIE, J. W. S. *Jl. Trop. Med. & Hyg.*, 1920, v. 23, 45–46.
SANDWITH, F. M. In *System of Med.* (Allbutt & Rolleston), 1909, v. 2, 864–83.

GUINEA.
CLAPIER. *Bull. Soc. Path. Exot.*, 1916, v. 9, 739–47.

KENYA.
COLLAMAN, J. C. J. *Kenya & E. African Med. Jl.*, 1927, v. 4, 103–113.
JEWELL, N. P. *East Africa Protectorate Ann. Med. Rep.*, 1918, Appendix 1, 70–80.
PHILIP, C. R. *Kenya & E. Africa Med. Jl.*, 1927, v. 4, 207–210.

MADAGASCAR.
EMILY. *Ann. de Méd. et de Pharm. Colon.*, 1926, v. 24, 170–83.
GIRARD. *Bull. Soc. Path. Exot.*, 1918, v. 11, 34–36.
MORIN, F. H. *Bull. Soc. Path. Exot.*, 1921, v. 14, 229–31.
MORVAN, VOIZARD, F. & BAIZE. *Bull. Soc. Path. Exot.*, 1928, v. 21, 20–25.
SANDWITH, F. M. In *System of Med.* (Allbutt & Rolleston), 1909, v. 2, 864–83.

MAURITIUS.
CHEVREAU, P. & DE CHAZAL, E. L. *Bull. Soc. Méd. Ile Maurice*, 1890, June 4.
HARLEY, J. *Med. Chir. Trans.*, 1864, v. 47, 55–72.
BOUR, E. F. *Bull. Soc. Méd. Ile Maurice*, 1912, v. 29, 82–88.
——. *Bull. Soc. Méd. Ile Maurice*, 1913, v. 31, 22.

MOROCCO.

BRUMPT, E. *Bull. Soc. Path. Exot.*, 1922, v. 15, 632–41.

CHARRIER, H. *Bull. Soc. Path. Exot.*, 1923, v. 16, 491–4.

JOB, E. *Bull. et Mém. Soc. Méd. des Hôpit. de Paris*, 1915, 3 Ser., 31 Ann., 1282–88.

RAYNAUD, L. *Bull. Office Internat. d'Hyg. Pub.*, 1928, v. 18, 1409–1412.

NATAL.

CAWSTON, F. G. *Jl. Trop. Med. & Hyg.*, 1919, v. 22, 189–90.

——. *Parasitology*, 1918, v. 11, 83–93.

——. *S. African Med. Rec.*, 1921, v. 19, 287–8.

——. *Brit. Med. Jl.*, 1923, Sept. 8, 437.

NIGERIA.

MORRISON, H., *Nigeria Ann. Med. & San. Rep. for 1927*, p. 85.

NACHTIGAL, G. *Sahara u. Sudan*, 1881, v. 2, 465.

SHARP, N. A. D. *Jl. Trop. Med. & Hyg.*, 1924, v. 27, 247.

NYASALAND.

CHRISTOPHERSON, J. B. *Brit. Med. Jl.*, 1923, Sept. 8, 437.

HOOTON, A. *Indian Med. Gaz.*, 1914, v. 49, 188.

HOWARD, R. *Jl. Trop. Med. & Hyg.*, 1910, v. 8, 68, 81–2.

TURNER, G. A. *Parasitology*, 1908, v. 1, 195–217.

WILTSHIRE, H. G. *Nyasaland Protect. Ann. Med. Rep. for* 1925, Appendix II, 30–33.

PORTUGUESE EAST AFRICA.

GARIN, H. *Med. Jl. S. Africa*, 1920, v. 15, 179–80.

LEAR, E. *1st Egypt. Congress of Med.*, 1905, *C.R.*, v. 2, Chirurgie, 174–209.

TURNER, G. A. *Parasitology*, 1908, v. 1, 195–217.

PORTUGUESE WEST AFRICA.

LEAR, E. *1st Egypt. Congress of Med.*, 1905, *C.R.*, v. 2, Chirurgie, 174–209.

RHODESIA.

MANSON, P. *Proc. Rhodesia Sci. Assoc.*, 1915, v. 13, 18.

SENEGAL.

LEGER, M. *Bull. Soc. Path. Exot.*, 1923, v. 16, 141–144.

LEGER, M. & BEDIER, E. *Bull. Soc. Path. Exot.*, 1923, v. 16, 276–8.

NEVEU, R. *Rev. Méd. et Hyg. Trop.*, 1920, v. 12, 35–6.

SIERRA LEONE.

BLACKLOCK, D. B. *Sierra Leone Ann. Med. & San. Rep. for* 1925, 68–72.

BLACKLOCK, D. B. & THOMPSON, M. G. *Ann. Trop. Med. & Parasit.*, 1924, v. 18, 211–34.

BUTLER, G. G. *Sierra Leone Ann. Rep. on the Med. Dept. for Year ended* 31*st Dec.*, 1915, 26–9.

EASMAN, M. C. F. *Jl. Trop. Med. & Hyg.*, 1924, v. 27, 305–307.

IRVINE, W. L. *U.S. Naval Med. Bull.*, 1916, v. 10, 725–36.

Report on Prevalence of Bilharziasis amongst the Pupils of the School for Sons of Chiefs, Bo. (Report received in Colonial Office, May 8, 1917).

Somaliland (Italian).
Veneroni, Carlo. *Riforma Med.*, 1926, v. 47, 9–10.
——. *Arch. Ital. Sci. Med. Colon.*, 1927, v. 8, 26–8.

South Africa (see also Natal and Transvaal).
Allen, J. F. *Practitioner*, 1888, v. 40, 310–20.
Auden, F. T. *Lancet*, 1904 (1), 1235.
Batho, R. *Brit. Army Med. Rep. for* 1870, 1872, v. 12, 502–504.
Briscoe, J. F. *Lancet*, 1916, Jan. 15, 155–6.
Cawston, F. G. *S. African Med. Rec.*, 1915, v. 13, 160–1 ; 1916, v. 14, 53–4 ; 1921, v. 19, 113–15 ; 1924, v. 22, 510.
——. *Lancet*, 1921, Aug. 13, 332.
——. *Med. Jl. S. Africa*, 1921, v. 16, 209–210.
——. *Brit. Med. Jl.*, 1922, June 17, 975.
——. *Jl. Amer. Med. Assoc.*, 1918, v. 70, 439–41.
——. *Jl. Trop. Med. & Hyg.*, 1924, v. 27, 283–4 ; 1925, v. 28, 193–5, 406.
Chute, H. M. *S. African Med. Jl.*, 1888, v. 4, 85–7, 89–91.
Davies, A. *St. Bart's. Hosp. Rep.*, 1884, v. 20, 181.
Egan, Ch. J. *Brit. Med. Jl.*, 1901, Apr. 13, 888.
Fritsch, G. *Arch. f. Anat. u. Physiol.*, 1867, 752.
Gatt, J. E. H. *Jl. Roy. Army Med. Corps*, 1907, v. 8, 65–7.
Gibson, K. W. B. *Med. Jl. S. Africa*, 1925, v. 21, 44–5.
——. *S. African Med. Rec.*, 1925, v. 23, 413–14.
Harley, J. *Med. Chir. Trans.*, 1864, v. 47, 55–72 ; 1869, v. 52, 379–87 ; 1871, v. 54, 47–62.
Kober, S. *S. African Med. Rec.*, 1926, v. 24, 407–408.
Le Dantec. *C.R. Soc. Biol.*, 1904, v. 56, 399.
Lyle, V. *Proc. Roy. Med. Chir. Soc.*, 1882, (2), v. 1, 9–10.
Manchego, F. M. *Lancet*, 1907, Sept. 28, 923.
Porter, Annie. *Proc. Roy. Soc. Med.* (Sect. Trop. Dis. & Parasit.), 1925, v. 18, 56–7.
Roux, M. *Caducée*, 1906, v. 6, 105–107.
Sambon, L. W. *Jl. Trop. Med. & Hyg.*, 1899, 177–9.
Sandwith, F. M. *Jl. Roy. Army Med. Corps*, 1906, v. 6, 217.
Sharp, C. G. Kay. *S. African Med. Rec.*, 1924, v. 22, 471–4.
Transkei. *Brit. Med. Jl.*, 1901 (1), 1000. [Correspondence.]
Turner, G. A. *Parasitology*, 1908, v. 1, 195–217.

Sudan.
Archibald, R. G. *Trans. Roy. Soc. Trop. Med. & Hyg.*, 1923, v. 16, 419–26.
Balfour, A. *Wellcome Res. Lab. Rep.*, 1904, v. 1, 51–2.
Bouilliez, M. *Bull. Soc. Path. Exot.*, 1915, v. 8, 604–610.
Christopherson, J. B. & Newlove, J. R. *Jl. Trop. Med. & Hyg.*, 1919, v. 22, 129–44.
Davies, D. S. *Trans. Roy. Soc. Trop. Med. & Hyg.*, 1927, v. 20, 436–46.
Dupont. *Rev. de Méd. et d'Hyg. Trop.*, 1910, v. 7, 207–208.
Lefèvre, R. *Bull. Soc. Path. Exot.*, 1924, v. 17, 720–22.
Maes, E. *Ann. Parasit. Humaine et Comparée*, 1924, v. 2, 82–5.
Nachtigal, G. *Sahara u. Sudan*, 1879, v. 1, 151.
Renoult, A. J. *Jl. de Méd. Chir. et Pharm.*, 1808, v. 18, 366–70.

Tanganyika.
Fairbairn, H. *Brit. Med. Jl.*, 1928, Jan. 14, 52.
Mense, C. *Arch. f. Schiffs- u. Trop.-Hyg.*, 1907, v. 11, 783.
Peiper, O. *Arch. f. Schiffs- u. Trop.-Hyg.*, 1910, v. 14, 232–59.
Railliet, A. *Bull. Soc. Zool.*, 1892, v. 17, 162.
Thomson, J. H. *Tanganyika Territ. Ann. Med. & San. Rep. for* 1926, 103–104.
Wolff. *Arch. f. Schiffs- u. Trop.-Hyg.*, 1909, v. 13, 162.

Transvaal.
Cawston, F. G. *Med. Jl. S. Africa*, 1917, v. 13, 30.

Tripoli.
Patane, C. *Ann. di Med. Nav. e. Colon.*, 1924, v. 2, 1–19.
Rizzo, C. *Riforma Med.*, 1927, v. 43, 555–6.

Tunis.
Anderson, C. W. *Arch. Inst. Pasteur de l' Afrique du Nord*, 1923, v. 3, 3–21.
——. *Bull. Soc. Path. Exot.*, 1922, v. 15, 954–6.
Anderson, Ch. & Gobert, E. *Arch. Inst. Pasteur de Tunis*, 1924, v. 13, 125–8.
—— —. *Bull. Soc. Path. Exot.*, 1924, v. 17, 35–7.
Anderson, Ch. & Lagoavere, J. L. *Bull. Soc. Path. Exot.*, 1927, v. 20, 23–5.
Brault, J. *Lyons Méd.*, 1891, v. 67, 449–53.
——. *Gaz. hebd. de Méd.*, 1891, Aug. 9, 332–85 ; v. 28, 32–4.
Cahier, L. *Arch. Méd. et Pharm. Milit.*, 1893, v. 21, 101–116.
Chatton, E. *Arch. Inst. Pasteur de Tunis*, 1918, v. 10, 199–243.
Chaurand, G. & Diacono, H. *Arch. Inst. Pasteur de l' Afrique du Nord*, 1923, v. 3, 94–6.
Conor, A. *Bull. Soc. Path. Exot.*, 1909, v. 2, 612–14, 486–8 ; 1910, v. 3, 446–9 ; 1911, v. 4, 627–9.
——. *C.R. Soc. Méd. Milit. France*, 1911, v. 1, No. 19.
——. *Arch. Inst. Pasteur de Tunis*, 1914, v. 9, 39–42.
Gobert, E. & Anderson, Ch. *Bull. Soc. Path. Exot.*, 1923, v. 16, 18–21.
Langeron, M. *Arch. Inst. Pasteur de Tunis*, 1924, v. 13, 19–67.
Leveque. *C.R. Soc. Méd. Milit. Franç*, 1911, Apr. 9.
Nicolle, C., Catouillard, G. & Gobert, E. *Arch. Inst. Pasteur de Tunis*, 1908, v. 3, 126–32.
Raynaud, L. *Bull. Office Internat. d' Hyg. Pub.*, 1926, v. 18, 1409–1412.
Villeneuve. *Gaz. hebd. de Méd.*, 1891, v. 38, 398 ; 1891, Aug. 29, 421.
——. *Marseilles Méd.*, 1892, v. 29, 152–7.

Uganda.
Castellani, A. *Annali Med. Navale*, 1903, Oct.
Castellani, A. & Low, G. C. *Arch. f. Schiffs- u. Trop.-Hyg.*, 1904, v. 8, 110–111.
Cook, J. H. *Brit. Med. Jl.*, 1909, June 5, 1356.

West Africa (Togo).
Peltier, M. *Bull. Soc. Path. Exot.*, 1925, v. 18, 592–6.

Zanzibar.
Zanzibar Protectorate Rep. on Med. Dept. for the Year 1914–7.

NORTH AMERICA.

CANADA.

CUTLER, M. *Jl. Amer. Med. Assoc.*, 1926, v. 86, 816–18.

U.S.A.

CUTLER, M. *Jl. Amer. Med. Assoc.*, 1926, v. 86, 816–18.
HERFF, F. *Trans. Texas Med. Assoc.*, 1894, v. 26, 412–16.
MOUCHET, R. *Bull. Soc. Path. Exot.*, 1918, v. 11, 297–300.
SANDWITH, F. M. In *System of Med.* (Allbutt & Rolleston), 1909, v. 2, 864–83.
VAN LIERE, E. J. *Jl. Amer. Med. Assoc.*, 1916, v. 67, 1369.
WALKER, R. E. *Med. Rec.*, 1900, Feb. 24.

CENTRAL AMERICA AND WEST INDIES.

FRENCH COLONIES (see also French Guiana, Guadeloupe, Martinique.)

REYNAUD, G. & LEGER, M. *Congres de la Santé Publique et de la Prévoyanc Sociale, Marseille,* 11–17 *Sept.* 1922, *Rapports,* 25–46.

GUADELOUPE.

COURTOIS-SUFFIT, P. J. & JAQUET, P. *Gaz. des Hôpit.*, 1912, v. 85, 833–7.
MATHIS, C. & BAUJEAN. *Bull. Soc. Méd. Chir. de l'Indo-Chine,* 1910, 174–8.
FABRE, H. *Bull. Soc. Path. Exot.*, 1925, v. 18, 653–4.

JAMAICA.

SILER, J. F. *Amer. Jl. Trop. Dis. & Prevent. Med.*, 1916, v. 3, 433–58.

MARTINIQUE.

LETULLE, M. *Rev. de Méd. et d'Hyg. Trop.*, 1904, v. 1, 46–8.
NOC, F. *Bull. Soc. Path. Exot.*, 1910, v. 3, 26–30.

PANAMA.

BRAYTON, M. D. *Proc. Canal Zone Med. Assoc.*, 1909.
——. *Jl. Amer. Med. Assoc.*, 1910, 1437–40.
BURRES, W. T. *Amer. Jl. Trop. Dis. & Prevent. Med.*, 1916, v. 3, 611–12.
DARLING, S. T. *Proc. Med. Assoc. Isthmian Canal Zone,* 1914, v. 5, 52–5.
HIGGINS, M. E. *Jl. Amer. Med. Assoc.*, 1906, No. 12, 887.
MONROE, F. F. *Proc. Med. Assoc. Isthmian Canal Zone,* 1916, v. 9, 77–8.

PORTO RICO.

CASSASQUILLO, H. F. *Bol. Asoc. Med. de Puerto Rico,* 1922, v. 16, 15–17.
GONZALEZ, M. I. *New Orleans Med. & Surg. Jl.*, 1916, v. 69, 352–94.
GONZALEZ MARTINEZ, F. *Rev. de Méd. Trop.*, 1904, v. 5, 193–4.
——. *Memoria Leida en la Assemble General de Membros de la Associacion Medica de Puerto Rico,* 1904, 32 pp.
HOFFMANN, W. H. *Porto Rico Rev. Pub. Health & Trop. Med.*, 1927, v. 3, 223–30.
LAMBERT, R. A. *Porto Rico Rev. Pub. Health & Trop. Med.*, 1927, v. 3, 231–4.

WEST INDIES.

HOFFMANN, W. H. *Arch. f. Schiffs- u. Trop.-Hyg.*, 1922, v. 26, 270–1.
HOLCOMB, R. C. *Milit. Surg.*, 1907, v. 20, 6.
——. *U.S. Naval Med. Bull.*, 1907, v. 1, 55–80.
JONES, S. B. *Jl. Trop. Med. & Hyg.*, 1922, v. 25, 25–7 ; 1923, v. 26, 253–4.
MANSON, P. *Jl. Trop. Med.*, 1902, v. 5, 384–5.

SOUTH AMERICA.

ARGENTINE.

BACIGALUPO, F. *C.R. Soc. Biol.*, 1925, v. 93, 1020–21.

BRAZIL.

ARANTES, A. *Ann. Paulist. Med. e Cirug.*, 1923, v. 14, 95–6.
CARDOSO, E. *Brazil-Medico*, 1923, v. 2, 239–40.
DA MATTA, A. *Amazonas Medico*, 1918, v. 1, 9–11.
DA SILVA ARAUJO, A. J. P. *Gaz. Med. da Bahia*, 1877, No., 499.
DA SILVA, P. *Arch. de Parasitol.*, 1909, v. 13, 283.
——. *Jl. Trop. Med. & Hyg.*, 1909, 159–63.
DE ALMEIDA, E. *Brazil-Medico*, 1924, v. 1, 307–308.
DE FARIA, G. *Mem. Inst. Oswaldo Cruz*, 1911, v. 3, 328–35.
LUTZ, A. & PENNA, O. *Mem. Inst. Oswaldo Cruz*, 1918, v. 10, 62–73.
SILVA, P. DE M. *Arch. f. Schiffs- u. Trop.-Hyg.*, 1912, v. 16, Beiheft 4, 485–7.
TORRES, O. *New Orleans Med. & Surg. Jl.*, 1918, v. 70, 611–24.

DUTCH GUIANA.

KHALIL, M. & LEE, C. U. *Rep. of the West Indian Med. Confer.*, July 8, 1921. Reprinted in *London School of Trop. Med.* (*Dept. of Helmin.*) *CollectedPapers*, 1922, Part 2, No. 17.
LAMPE, P. H. J. *Proc. Roy. Soc. Med.*, 1927, 1510–16.
——. *Geneesk. Tijdschr. v. Nederl.-Indie*, 1925, v. 65, 546–60.

FRENCH GUIANA.

BRIMONT. *Bull. Soc. Path. Exot.*, 1909, v. 2, 413 and 423.
HENRY. *Rev. de Méd. et d'Hyg. Trop.*, 1910, v. 7, 275–6.
LEGER, M. *Bull. Soc. Path. Exot.*, 1917, v. 10, 464–7.

VENEZUELA.

BALFOUR, A. *Brit. Med. Jl.*, 1914 (1), 915.
RISQUEZ, J. R. *Gac. Med. de Caracas*, 1916, v. 23, 25–6.
——. *Bull. Soc. Path. Exot.*, 1921, v. 14, 382–5.

AUSTRALIA.

BEVERIDGE, W. W. O. *Jl. Roy. Army Med. Corps*, 1907, v. 9, 323–4.
COBBOLD, T. S. *Brit. Med. Jl.*, 1876 (1), 870–1.
——. *Veterinarian*, 1876, July 22, 487–9.
HOLLAND, E. P. & WOODWARD, E. A. *Med. Jl. Australia*, 1924 (2), 606.
MCWHAE, D. M. & JAGGER, T. R. *Med. Jl. Australia*, 1921 (2), 217–19.
MADDEN, F. C. *Intercolonial Jl. Med. Australasia*, 1902, v. 7, 317–29.
MORTON, J. *Australian Med. Gaz.*, 1910, v. 29, 79.
NELSON, W. H. *Australian Med. Gaz.*, 1912, v. 32, 482–3.
NEWMARCH, B. J. *Australian Med. Gaz.*, 1907, July 20.
SMITH, P. E. WALTON. *Med. Jl. Australia*, 1917 (1), 79–80.

APPENDIX II.

NOTE ON RELATION OF IRRIGATION TO CLIMATE AND TO NUTRITIVE VALUE OF CROPS.

In addition to such comparatively close relations to health matters as have been described in the foregoing report, irrigation may have other less direct effects on health.

The conversion of many thousands of acres of dry, barren land into an area of perpetually moist soil, intersected by open water channels and perennially covered by vegetation, is likely to have an effect upon climate. Atmospheric humidity will be increased and even rainfall. Figures of irrigated acreage and atmospheric humidity in such places as Egypt and the Sudan might make an interesting study. Certainly residents in these countries are of opinion that since the irrigation of wide areas formerly desert, the " dry heat " characteristic of the climate has altered in the direction of approximation to tropical " moist heat."

In this connection it is interesting to note that a part of an irrigation and agricultural scheme for Northern Africa, which was described in the press recently, consisted of the creation, by letting in the sea, of a vast inland lake with a view to bringing about a rainfall in the present waterless desert.

The effect of irrigation on crop values is mainly an economic issue. An indication has been given in the report that further study of this might enable agriculturists and hygienists to co-operate more closely. A new phase of the problem has, however, come to light recently. It is generally known that recent work has shown a number of disease conditions—or at least conditions of inferior health—to be attributable to diets insufficient in quality though not in quantity. It will suffice to instance the harmful, but not yet fully understood, effects of a staple diet of polished rice. McCarrison (*Ind. J. Med. Res.*, 1928, v. 15, 915–20) has brought forward evidence that some difference in nutritive value of crops (apart altogether from yield) may be observed according to the conditions of water supply of the crops while growing. Particulars of the history of the land and of the treatment of the crop are given. McCarrison's conclusions are reproduced in full.

" (1) The nutritive value of rice is influenced by the conditions of water supply under which the crop is grown.

" (2) Rice grown on puddled fields in which a layer of water is always allowed to remain has a nutritive value approximately one-third less than the same rice when grown under dry rain-fed conditions.

" (3) The lower nutritive value of rice grown under wet conditions is due, in part at least, to its lower content of vitamins of the water-soluble-B class.

" (4) It seems probable that the conditions of cultivation of rice, especially in regard to water supply during the growth of the crop, is a factor of importance in determining the endemicity of beri-beri."

APPENDIX III.

RULES ENFORCED IN NEW IRRIGATION CONCESSIONS IN THE SUDAN.*

1. Irrigation channels should be constructed on a higher level than the surrounding land, so that when the flow of water in them ceases they may drain dry.

2. They should be constructed of such material and in such manner as to prevent leakage.

3. Their banks and beds should be kept in good repair, and the beds even, to prevent the formation of pools.

4. " Dead ends " of irrigation channels should be reduced to the smallest size compatible with efficiency, so that water will not stagnate in them.

5. Vegetation should be periodically cleared out of the channels.

6. Sluices should be constructed so that there is no leakage to form stagnant puddles.

7. Where possible, fish should be introduced, and kept in the main channels to destroy the larvae.

8. Lands where water is apt to stand should have proper surface drainage.

9. Crops, such as sugar-cane, rice, and others which require to stand in water, should not be grown within half a mile of any town or village.

10. If an engine or pump should happen to break down, particular care should be taken to deal with stagnant pools, and petroleum should be used where necessary.

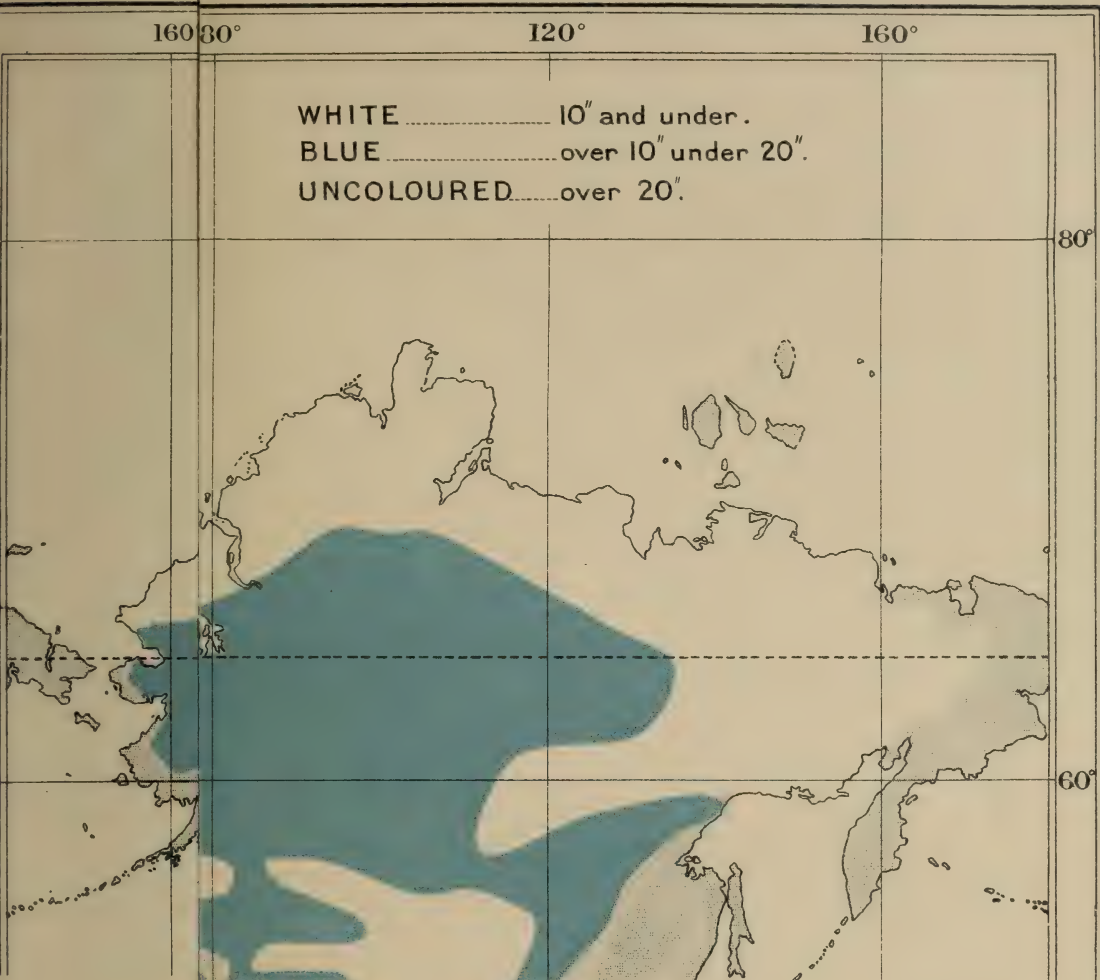
11. Cases of malarial fever, and any prevalence of mosquitoes, should be notified to the governor of the province by the manager of the concession.

---

* Quoted by Balfour in *Third Report of Wellcome Res. Lab., Khartoum, 1908*, p. 67.

HES AND LESS

7.



MAP I. DISTRIBUTION OF RAINFALL OF 20 INCHES AND LESS

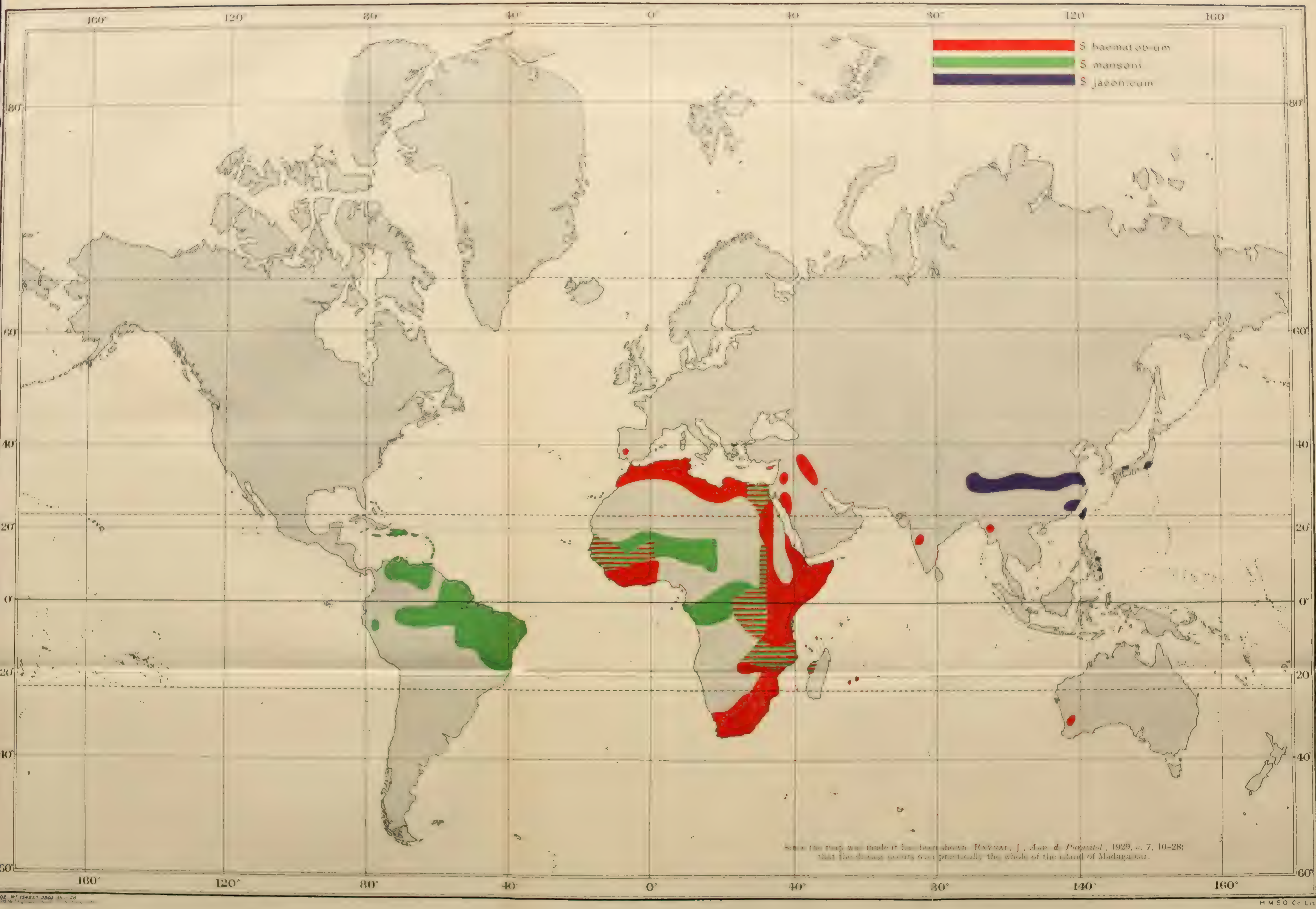
COMPILED FROM DATA IN "THE CLIMATES OF THE CONTINENTS." W. G. KENDREW. 1927

H M S O Cr. Lith

MIASIS

MAP II. DISTRIBUTION OF SCHISTOSOMIASIS

AFTER MANSON AND BYAM AND ARCHIBALD



MALARIA

MAP II. DISTRIBUTION OF SCHISTOSOMIASIS

120°
160°
SCHISTOSOMIASIS.


MALARIA
160°
120°
0°
40°
80°
120°
160°

MALARIA

MAP III. DISTRIBUTION OF INDIGENOUS MALARIA
(AFTER JAMES)

E.M.B. 18

THE COMPOSITION OF PASTURES

By

J. B. ORR, D.S.O., M.C., M.A., M.D., D.Sc.,
Director of the Rowett Research Institute, Aberdeen.

JUNE, 1929.

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller.

1929.
Price 9*d*. Net.

70–221–18.

CONTENTS.

(36624) Wt. P3029/585/2073 2500 6/29 Harrow G.3

PREFACE.

Pasture is the raw material for the formation of milk, meat, mutton, wool, hides and other products of cattle and sheep. In many pastoral areas it is the only raw material used. Even under conditions of intensive production as in England, it has been estimated that pastures constitute three-fourths of the material given to grazing animals to transform into these products. Consumption in the United Kingdom of live stock products mostly derived from grass-lands has been estimated at about £400,000,000 per annum. The consumption of wheat is less than £100,000,000.

The production and marketing of these grassland products is of special economic importance to the British Empire. More than half of the grassland products shipped from all countries in the world is imported into Great Britain. We import over 60 per cent. of the sea borne exports of dairy products and beef, and over 90 per cent. of the sea borne exports of mutton and lamb.

The limiting factor for the production of these products is not the number of cattle and sheep, which can be increased indefinitely, but the raw material which they transform, i.e. the pastures. Pasture is, therefore, a subject of research which is pre-eminently worthy of intensive research on an Empire basis.

In this review pastures are considered not as a crop, but as a feeding-stuff or raw material, and the most recently acquired knowledge of nutrition has been applied to problems connected with the feeding value of pastures. It is shown that the chemical composition of a pasture is an indication of its feeding value. It is also shown that some pastures are deficient in certain nutrients and that if these nutrients are supplied to the soil in the form of fertilisers or direct to the animal there is increased utilisation of the pastures, and the grazing animals are maintained in better condition. The results of researches carried out in various parts of the Empire on these lines during the past few years give reason to believe that grassland products can be greatly increased.

In the past, increase in knowledge or the application of knowledge to biological problems often depended upon the spasmodic efforts of individuals. Hence advance was frequently slow, and some of the information obtained was either lost sight of or its economic significance was not recognised. During the past few years this haphazard halting advance has been replaced by co-operative team-work, not only between individuals but between institutions.

Co-operative team-work upon the pasture problem is essential on account of its many different aspects. The present review deals

with the physiological or veterinarian aspect. But even though limiting itself to this one aspect it has been necessary to take account of the work of pathologists and bacteriologists on the one hand and of plant breeders and soil chemists on the other. The knowledge which must be applied to the great economic problem of developing pasture lands must be drawn from a number of sciences.

Co-operation in the pasture research referred to in this review has been secured largely through the instrumentality of a Sub-Committee of the Committee of Civil Research, including a group of scientists interested in different branches of biology. This Committee has given continuous advice and guidance on the more fundamental work upon the composition of pastures carried out in Great Britain and also on some practical experimental work in the Colonies. The Empire Marketing Board, to which the Committee of Civil Research has from time to time made recommendations, has made grants to various Governments within the Empire for investigations on the lines of research dealt with in this volume.

As a result of these activities information from different branches of science is being brought to bear upon the problem of increased production of grasslands. There is continuity of effort and there is a free and informal exchange of information between the workers and institutions in different parts of the Empire. Thus, the work on iodine deficiency in Canada is throwing light on the problem of goitre in Australia and New Zealand. The work of the Waite Institute in Australia on transpiration of plants growing on different types of soil is yielding information which is being considered in connection with the improvement of pasture lands in the semi-arid parts of Africa. The pioneer work in connection with phosphorus deficiency in South Africa has been applied in Australia and New Zealand. The results of the work on "bush sickness" in New Zealand have been applied successfully in the prevention of a similar disease in Kenya Colony. The work on the composition of pastures at Cambridge and Aberdeen has thrown a flood of new light on the question of deficiences in pasture which occur in practically all countries.

The recent growth of scientific co-operation between the constituent parts of the Empire could not be better exemplified than in this record of concerted endeavour to foster the better exploitation of the Empire's grasslands.

L. S. AMERY.

16th April, 1929.

THE COMPOSITION OF PASTURES.

I.—PASTURE RESEARCH FROM THE VETERINARIAN POINT OF VIEW.

During the last two or three years research in pastures has been largely influenced by recent developments in our knowledge of the food requirements of animals. The early investigations on nutrition were concerned chiefly with the requirements for energy-yielding food constituents and for protein, and in arranging diets, attention was directed almost exclusively to the great "oxidisable" compounds in food. Calories and the "protein ratio" were taken as the measurements of the nutritive value of foodstuffs.

Recent physiological research and clinical observations have given us a much wider conception of the food requirements of animals. We now know that in addition to these oxidisable compounds, which form by far the greater part of the dry matter in foodstuffs, there are a number of other substances which are equally essential for growth and health.

This fuller and truer conception of food requirements has opened up new fields of investigation in dietetics. Since the War there has been a vast amount of work done both in the way of chemical analysis and feeding experiments, to determine to what extent essential food constituents, other than proteins, fats and carbohydrates, are present in different foodstuffs and the effects of a deficiency of them on the health and rate of growth of animals. This work has shown that a number of pathological conditions which have been described and studied by clinicians for a long time, but the causes of which were obscure, are due to deficiencies of one or other of these constituents.

This recently acquired information has given a stimulus to the study of the chemical composition of pastures. Investigations have been carried out from the point of view of the veterinarian whose interest is not in pasture as a crop, but rather in the extent to which the chemical composition of the pasture is adjusted to the requirements of the grazing animal.

The constituents on which attention has been focussed in this recent work can be classified broadly in two groups, viz., vitamins and mineral elements. In feeding tests it has been found that pastures like other green foodstuffs are rich in vitamins, so that, so far as is known, there is no shortage of these food factors in green pastures.

The subject is, however, by no means exhausted. It is known that methods of preserving fodder affect its vitamin content and we are not certain that there is no vitamin deficiency in pastures of low nutritive value. On the whole, however, the subject of vitamins in pastures appears to be of less immediate practical importance than that of minerals and proteins. The discussion in this brief review is confined to these constituents.

II.—NUTRITIVE VALUE AND COMPOSITION OF GOOD PASTURES.

It is the common experience of stockmen that good pasture is the best feeding stuff for herbivora. The reason for the high nutritional value of pasture is apparent when we compare its composition with that of other foodstuffs. Milk can be taken as the food of ideal composition for growing animals and also as approximating to the ideal for milk-producing animals. In the following table the mineral and protein content of good pasture and some other representative feeding stuffs are compared, using cow's milk as the standard. The comparison is made on amounts of equal energy yielding or caloric value because it is the energy yielding value of a ration which determines the amount which must be fed. Only the minerals required in largest amounts are dealt with. Though we have reason to believe that the other essential mineral elements are present in sufficient amounts in good pastures, we have little definite information about the percentages present either in pastures or indeed in any other feeding stuff.

TABLE I.

Comparison of mineral content of good pasture with that of some other foodstuffs, with milk as the standard.

1,000 calorie portions contain the following amounts in grams :—

	CaO.	P_2O_5.	Na_2O.	K_2O.	Cl.	Protein.
Cow's milk	2·38	3·43	0·81	3·21	1·4	52·00
Good pasture	3·64	2·75	0·94	11·54	3·5	65·00
Maize	0·03	1·83	0·13	1·36	0·001	29·00
Wheat	0·14	2·75	0·13	1·59	0·2	35·00
Potatoes	0·28	1·60	0·49	5·56	0·3	21·00
Turnips	1·18	1·96	0·33	5·40	0·42	24·19
Molasses	5·35	0·56	1·02	10·26	3·56	26·44
Decorticated cotton cake.. ..	1·22	11·26	0·24	8·05	0·11	164·50

It will be seen that there is a fairly close resemblance between the mineral and protein content of good pasture and that of cow's milk. None of the other foodstuffs are so well balanced. All of them are deficient in one or more minerals and with the exception of cotton cake, which is representative of protein-rich concentrates, they are all relatively deficient in protein. The close correspondence of the mineral content of a good pasture to the mineral requirements of the animals is doubtless one of the most important of the factors which determine the well-known high nutritive value of good pasture for promoting growth and maintaining health in stock.

The figures given in the above table as the amounts of the different constituents present in the quantity of good pasture which would yield 1,000 calories, are the averages of a number of samples taken from cultivated grass lands where the natural herbage has been improved by cultivation, manuring and sowing of grass seed mixtures. It is interesting to note that the farmer, in producing a crop of grass, which from his practical experience he considers to be of high feeding value, has produced an herbage, which chemical analysis has shown to be very similar in composition to milk. As pastures are improved the chemical composition tends to approximate more and more closely to the composition of cow's milk. Hence good pastures, from whatever area they may be collected, tend to have a somewhat similar composition. The following table gives the average composition of 24 samples of cultivated pasture collected from different parts of Scotland and England.

TABLE II.

Average composition of 24 samples of cultivated pastures. Results expressed in percentages of Dry Matter.

	Percentage.
CaO	1·004
P_2O_5	0·735
Na_2O	0·246
K_2O	3·177
Cl	0·950
Protein	17·656
Total ash	9·787
Silica-free ash	6·637
Fibre	23·0
Calories per 100 gms.	268·9

A further series of 24 samples yielded very similar results to the above, which can be taken as representative of the composition of good cultivated pasture in Great Britain.

III.—COMPOSITION OF UNCULTIVATED OR NATURAL PASTURES.

Uncultivated or natural herbage differs from cultivated in being, in general, poorer in mineral elements and also, though to a less extent, poorer in protein. The following table gives an indication of the composition of some samples of uncultivated pastures from various grazing areas.

TABLE III.

Mineral content of samples of pastures from different areas.

Percentage of Dry Matter.

	Silica-free ash.	CaO.	P_2O_5.	Na_2O.	K_2O.	Cl.	Protein.	Cals. per 100 grams.
British cultivated pasture.	6·64	1·00	0·74	0·25	3·18	0·95	17·66	269
1. Scottish Lowland hill pasture.	5·63	0·57	0·65	0·23	3·27	0·70	15·25	268
2. West of Scotland hill pasture.	4·77	0·40	0·59	0·16	2·62	0·56	15·88	265
3. Naivasha, Kenya Colony.	5·46	0·92	0·98	0·14	1·87	0·41	9·37	—
4. Molo, Kenya Colony	2·57	0·46	0·22	0·02	0·72	0·17	6·56	—
5. Falkland Islands ..	4·70	0·21	0·52	0·56	2·16	0·85	13·75	243
6. Nigeria, West Africa	—	0·43	0·24	—	—	—	—	—
7. District in Norway where *Osteomalacia occurs (hay).	—	0·185	0·155	—	—	—	—	—
8. Farm in south-west of Scotland where *Croitich occurs.	2·82	0·21	0·29	0·12	1·51	0·52	—	—
9. Armoedsvlakte (South Africa) where *Styfsiekte occurs.	—	0·50	0·07	—	—	—	—	—
10. Area in Australia in which deficiency diseases occur.	—	0·34	0·24	—	—	—	—	—

* Deficiency Diseases.

Samples 1 to 5 were taken in the course of an investigation carried out from the Rowett Institute. The figures in each case are for a particular sample which is representative of the area and corresponds fairly closely with the average quality. When the samples were taken, information was obtained with regard to the feeding value of the pastures as judged by their carrying capacity and the rate of growth and mortality of the grazing animals (sheep). The figures for Nigeria, obtained from Dr. du Toit[1] of Onderstepoort, Pretoria, are the averages of eleven samples. Samples 7 to 10 are given as examples of types of pasture which are so deficient that diseases occur in the animals grazing on them. These deficiency diseases are considered later (pp. 15–19).

The information available seems to show that there is a rough parallelism between the feeding value of a pasture and the percentage of silica-free ash which represents the total usable minerals. In general, the poorer the pastures are in mineral matter the lower the carrying capacity, the slower the rate of growth of the young animals and the higher the incidence of disease. Thus, for example, sample No. 1, with a silica-free ash percentage of 5·63 is from a moderately good hill grazing in the South of Scotland which supports Cheviot sheep; sample No. 2, with a silica-free ash percentage of 4·77 is from a hill farm in Argyllshire with the smaller, slower growing Black-faced sheep. It is well known that the mortality in sheep in the Western Highlands is higher than that in the Lowland hills.

Of the two samples from Kenya Colony, one from the district of Naivasha has a silica-free ash percentage of 5·46 and one from Molo 2·57. In a test that was carried out it was found that lambs grazing at Naivasha increased from 25 to 80 lb. in weight in 14 months, while lambs grazing at Molo increased in weight from 35 to 58 lb. in 12 months. The average weight of fleece at Naivasha was 5·6 lb. compared with 4·3 at Molo.

In the Falkland Islands, from which the poorest sample in this group was obtained, the fertility and mortality figures, as given by Munro[2], were: lambs born, 90 per cent.; surviving at dipping 52 per cent.

In the case of the Nigerian samples the figure for silica-free ash is not available, but the figures for calcium and phosphorus show that compared with cultivated pastures they are poor in minerals. Animals there are slow growing. Cows do not have their first calf until they are about five years old.

These examples illustrate the fact that a pasture poor in minerals is ill adapted for maintaining rapidly growing modern breeds in health.

While the figure for silica-free ash is a measure of the total mineral nutrients, it should be noted that the proportions of the different minerals vary in different pastures. Thus, sample No. 4 is much poorer in phosphorus than calcium. Phosphorus is evidently the limiting factor. Sample No. 5 on the other hand is much poorer in calcium than phosphorus. In the latter case calcium is the limiting factor. The total silica-free ash is, therefore, only a very rough measure of nutritive value so far as minerals are concerned. Any one of the individual minerals may become the limiting factor for either growth or health.

It is a general law in nutrition that the faster the rate of growth of an animal, the richer must the food be in constructive material required for bone and soft tissue formation. This is illustrated in the comparison of the average rate of growth of the young of different species with the concentration of mineral matter in the milk of the species.

TABLE IV.

Modification of Table by Pröscher and Abderhalden.

Species.	Time in days to double weight after birth.	The Milk of the Species contains :	
		Ash, per cent.	Ash in grams per 1,000 calories.
Man	180	0·25	3·7
Cow	47	0·72	10·5
Pig	14	1·03	10·9
Rabbit	6	2·50	15·0

It is seen that in the milk of the faster growing species, not only is the percentage of ash higher, but the proportion of ash to energy-yielding constituents is also higher. In accordance with this law, mineral rich pastures will support rapidly growing animals in health, whereas mineral poor pastures will support only animals with a slow rate of growth. There is thus an equilibrium between the rate of growth of breeds of grazing animals and the mineral content of the pastures in the areas in which the breed is evolved.

Modern improved breeds of cattle with a rapid rate of growth have been evolved in districts with improved cultivated pastures. The improvement of the breed and the pastures have gone hand in hand and are closely connected. But in developing animal husbandry in new countries, sires of improved breeds have been imported to " grade up " native cattle without any " grading up " of the pastures. The common result has been that as the " grading up " process proceeds, mortality increases. The natural herbage which is able to support in health slower growing native cattle, which have evolved on this herbage, is too poor in constructive material to support more rapidly growing animals. The equilibrium between the grazing animal and the herbage is upset, and the resulting mortality and sterility is really a natural process tending to the elimination of a type whose rate of growth and of production is greater than the herbage can support.

On these natural pastures which are poor in mineral matter, the grazing animal instinctively chooses the herbage which is richest in minerals. In a survey of pastures in Scotland, samples were taken of herbage actually eaten, and within the same grazing area, other samples which were not eaten. The following table (Godden)[3] shows the average composition of 35 pairs of corresponding samples :—

TABLE V.

	Percentages on Dry Matter.	
	Grass eaten.	Grass not eaten.
CaO	0·56	0·30
P_2O_5	0·60	0·37
Na_2O	0·41	0·17
K_2O	2·60	1·61
Cl	0·60	0·33
Protein	15·87	11·37
Silica-free ash	5·49	3·13
Fibre	25·2	29·3

It has recently been shown at the Plant Breeding Station, Aberystwyth[4], that the part of the plant selected by the sheep in grazing is the part which is richest in silica-free ash. On poor pastures where

parts have been treated by the application of slag or other mineral fertilisers which increases the mineral content of the herbage (p. 29) it is usually found that the grazing animals prefer the part so treated to the adjacent untreated parts.

An exaggeration of this instinct of the grazing animal to choose the herbage best adapted to its requirements often leads to the eating of abnormal substances such as earth or bones by animals grazing on deficient pastures. In several parts of the world it is customary for wild herbivora to eat earth in certain special places. It has been found that these patches called "salt licks", are richer in usable minerals than the surrounding soil. The native herdsmen in some of the pastoral tribes of Africa take advantage of natural salt licks for maintaining the health of their herds. The animals are taken to them at regular intervals and it is a well established fact that, should anything prevent the visit to the salt licks, the animals begin to show signs of malnutrition. On pastures very poor in phosphorus, cattle develop a hunger for bones. Indeed bone chewing in some parts of the world is regarded as a definite clinical sign of phosphorus starvation. Theiler and his co-workers have shown that in phosphorus deficient pastures in South Africa the degree of "osteophagia" or bone chewing corresponds with the degree of phosphorus deficiency in the pastures.

IV.—DISEASES DUE TO DEFICIENCY OF MINERALS IN PASTURES.

The results of systematic investigations carried out during the past few years have proved that deficiency of minerals in pastures may be the cause of certain nutritional diseases. This conclusion has been reached by several workers independently in different parts of the world. A review of the literature brings out the fact that similar observations had been made by some of the older workers investigating diseases endemic in certain areas. In most cases the general nature of the conclusions reached by these early workers is in line with those being drawn by present day investigators. But whereas most of the earlier workers confined their observations to a small area and appeared to have had the idea that they were dealing with a local condition confined either to that area or a few other such areas, we now recognise that we are dealing with a condition which is practically world wide in its distribution.

The most common forms of deficiency diseases are believed to be due to deficiency of phosphorus or calcium. They are characterised by general unthriftiness, emaciation, stiffness of gait and inco-ordinated movement. Post mortem examination usually shows softness or fragility of the bones. A very common symptom is " depraved " appetite which leads to the chewing or eating of substances which have no attraction for a healthy animal (see p. 17). Bone chewing is one of the commonest expressions of this depraved appetite.

The names given to the condition in different parts of the world are usually descriptive of the main symptoms. In older European literature such terms as " Hinsch " (emaciation), " Lecksucht " (licking disease, " pica " or depraved appetite), " Knochenbrüchigkeit " (brittle bones) were used. In South Africa the conditions have been termed " Styfsiekte " (stiff-sickness) ; in Australia, " Cripples ", " Stiffs ", " Rickets ", " Wobbles " ; in parts of the United States, " Creeping Disease ".

In Europe the disease has occurred generally in winter when animals are fed on hay, and hence most of the analytical work in investigations on these deficiency diseases has been done upon hay. The following table from Klimmer and Schmidt[5], who give a review of the subject in Europe up to 1904, compares the phosphorus and calcium content of hay which causes disease with that of normal hay. The large number of authors quoted is an indication of the number of European workers who investigated this problem.

TABLE VI.

	Hay causing " Brittle Bone ". 100 parts of Dry Matter contain :	
According to :	CaO.	P_2O_5.
Karmrodt	0·68	0·22
,, ...	0·90	0·23
Stohmann	0·70	0·26
Wolff	0·63	0·26
Morgen	0·37	0·20
,, ...	0·67	0·26
Stutzen	1·52	0·29
Nessler	—	0·49
,, ...	—	0·35
,, ...	—	0·28
,, ...	—	0·27
,, ...	—	0·28
Germain	0·30	—
Roloff	0·70	0·26
Dircks' Forest Hay	0·19	0·155
,, ,, ,, ...	0·28	0·14
,, ,, ,, ...	0·28	0·13
Kellner	—	0·22
Meadow hay	—	0·26
Kellner	—	0·28
Temporary Ley	—	0·28
Klimmer and Schmidt :		
Plateau..	0·50	0·27
Valley	0·35	0·32
	Normal Hay. 100 parts of Dry Matter contain :	
According to :	CaO.	P_2O_5.
Hoffmeister	1·43	0·81
Weiske	1·12	0·55
Karmrodt	0·95	0·43
Johnson	—	0·57
Wolff	1·43	0·43
,, ...	1·06	0·58
,, ...	1·60	0·48
V. Gohren and Langer	—	0·55
Wolff	1·11	0·50
,, ...	1·18	0·46
Stutzen (according to Bongartz) ..	0·95	0·42

The above figures show that compared with normal hay, all the hays which cause brittle bone are very poor in phosphorus and many are also very poor in calcium. The fact that phosphorus is more uniformly low than calcium suggests that deficiency of this element is the more important factor in causing the disease.

In some areas of the West of Scotland a condition known as "croitich" occurs in sheep. The chief feature of the disease is softening or fragility of the bones. Analysis of the pasture in an area where this condition occurred showed that the percentages of calcium (as CaO) and phosphorus (as P_2O_5) were ·21 and ·29 respectively, which are only about half the average for hill pastures in the West of Scotland (p. 10).

In South Africa, styfsiekte (stiff-sickness) and lamsiekte (lame sickness) accompanied by bone chewing occur in certain areas. The extensive researches of Sir Arnold Theiler[6] and his co-workers have shown that both these conditions are primarily due to phosphorus deficiency and can be prevented by supplying phosphorus rich substances or even by feeding inorganic phosphates. The immediate cause of lamsiekte is now regarded to be bacterial. The bacteria are ingested by cattle when chewing rotten bones. The feeding of phosphorus rich substances prevents the depraved appetite and thus prevents the ingestion of the bacteria and so indirectly prevents lamsiekte. The pastures on which these diseases occur are all low in phosphorus. Some of the samples which have been analysed show extreme poverty, in some cases the percentage (as P_2O_5) being less than 0·1 compared with 0·7 to 0·8 for a good pasture. These workers have shown that the intensity of the osteophagia or depraved appetite, which is a constant symptom of these diseases, corresponds with the degree of phosphorus deficiency in the pasture.

Pathological conditions which are attributable to deficiency of either calcium or phosphorus are also common in Australia. Where chemical analysis of the pastures has been made it has been shown that the mineral content is lower in affected areas than in non-affected areas. Deficiency of phosphorus seems to be more important than deficiency of calcium, though frequently the two are concurrent. The following table given by Henry[7] is an example of the results obtained in these investigations.

TABLE VII.

Percentages in Dry Matter of Pastures.

	CaO.	MgO.	K_2O.	P_2O_5.	
(1) ..	0·42	0·19	1·53	0·56	Non-affected area.
(2) ..	0·41	0·21	1·48	0·56	
(3) ..	0·44	0·17	1·05	0·30	Affected area.
(4) ..	0·42	0·17	0·93	0·30	
(5) ..	0·34	0·15	0·72	0·24	
(6) ..	0·33	0·15	1·02	0·27	

In New Zealand, phosphorus deficiency was the cause of disease in milk cows in certain districts. The cows showed the characteristic stilted gait and on post mortem examination were found to have soft and spongy bones. The discovery by Reakes[8] and his co-workers that the disease could be prevented by the administration of bone meal or syrup of phosphate of iron or by treatment of the pastures with super-phosphates was instrumental in popularising the practice of top-dressing with super-phosphates, which has had such an influence in the improvement of New Zealand pastures.

An interesting feature about the occurrence of these diseases is that they are much more prevalent and severe in drought. It will be seen later (p. 27) that drought affects the mineral content of pastures, especially the percentage of phosphorus, which becomes very markedly reduced.

The conditions referred to above are due mainly to deficiency of phosphorus or calcium—the two minerals which are required in largest amounts. Deficiency of other minerals, however, may also cause disease. Of special interest are iodine and iron, which are only needed in comparatively small amounts. A good deal of research work has been done on these within recent years.

In various parts of the world a disease called goitre occurs in cattle and sheep. The chief feature is enlargement of the thyroid gland. There is usually a high mortality in the offspring of goitrous animals. One of the best known investigations of this condition was one with sheep in Michigan, U.S.A., where the disease was very prevalent. The feeding of salts rich in iodine was found to prevent the occurrence of

the disease. In many parts of Canada goitre occurred periodically in cattle and young sheep. Tests carried out by the Animal Husbandry Division of this Dominion showed that administration of potassium iodide to pregnant dams was followed by the disappearance of the disease. It is believed that there is a deficiency of iodine in many parts of the world, and that in some parts there may be a deficiency which, though not sufficiently marked to produce goitre, may affect the health of the animals. Investigations are now being carried out in various countries to determine the areas in which deficiencies occur and the effect of the deficiency on grazing animals.

In certain districts in New Zealand there occurs a disease in cattle and sheep known as " bush-sickness ". It is characterised by extreme anaemia and emaciation. The work of Aston[9] and others seems to show that it is caused by deficiency of iron in the pastures. The feeding of iron salts both cures and prevents the condition. A similar disease occurs in a district in East Africa where it is termed " Nakuruitis ", and also in King Island, Tasmania. A disease called " Pining " in sheep, which occurs in fairly well-defined areas in the South of Scotland, appears to be of the same nature. Whatever the cause of these conditions may be the administration of iron salts both cures and prevents them. The following illustrations (1 & 2) show the effects of feeding iron salts to cattle grazing in an area where Nakuruitis occurs.

The effects of deficiency of phosphorus, calcium, iodine and iron have been studied more extensively than the effects of deficiency of other minerals. It is known, however, that lack of common salt, which provides sodium and chlorine, causes malnutrition, especially in milk cows. But the question of possible deficiency of manganese, zinc, copper, boron and other elements which are known to have an influence on the physiological processes of the body have not been studied. We have very little knowledge as to the amounts of these present in different pastures or as to the amounts which animals require. It may well be that minute traces of some of these elements which are present as impurities in salt licks and mineral mixtures sometimes fed to grazing animals, may be responsible to some extent for the beneficial effects at present credited to other substances. There is here a wide field for research.

It should be noted that deficiencies sufficient to cause diseases occur only in limited areas in the countries named above and further that the existence of deficient areas is not confined to these countries. They occur practically all over the world.

V.—EFFECT OF DEFICIENCIES ON RATE OF PRODUCTION.

It has been shown above that the administration to grazing animals of whatever is deficient in the pasture prevents the onset of deficiency diseases. As a result of further observations it has been found that in addition to the prevention of disease the rate of growth and production is increased.

In the extensive tests carried out by Theiler, du Toit and Green[10] in South Africa, on the prevention of lamsiekte and styfsiekte by the administration of bone meal and common salt which make good the major mineral deficiencies of the pastures, notes were taken of the rate of growth of young beef cattle. Some of the animals received the mixture at the rate of 3 oz. per head per day, others grazing in the same pasture, receiving no supplementary feed, served as controls. The result is shown in the following illustration 3 and table below.

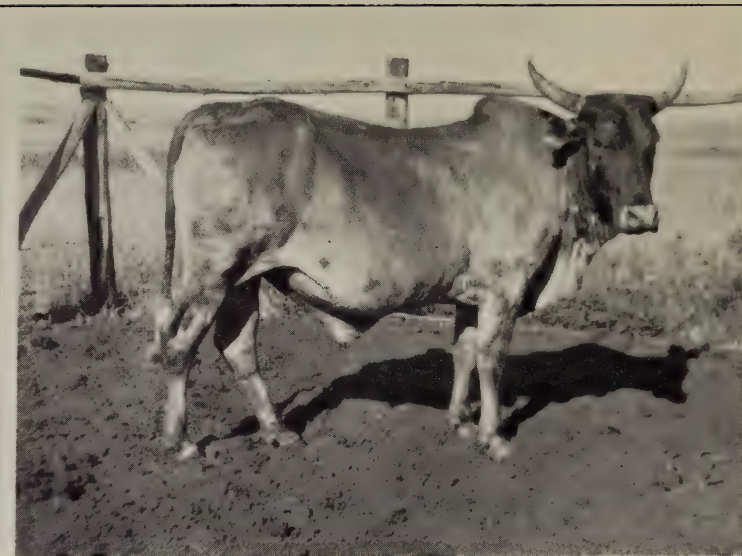
TABLE VIII.

Showing effect of bone meal and salt (supplying calcium, phosphorus, sodium, chlorine) on the growth of cattle on pastures markedly deficient in phosphorus.

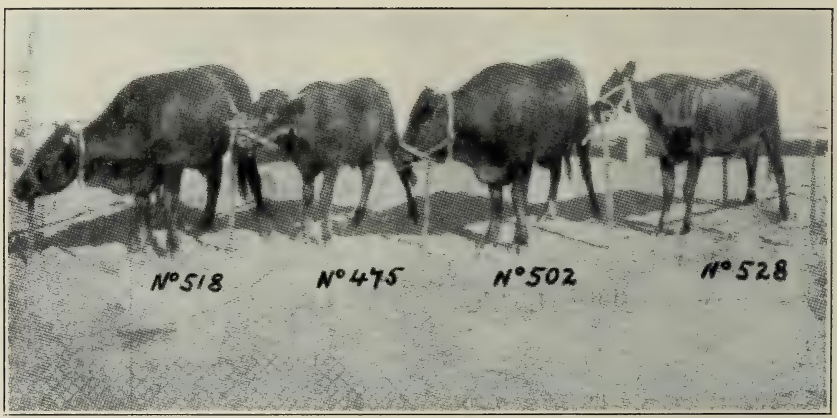
Weight.	No. 518.	No. 475.	No. 502.	No. 528.
January, 1922	310 lb.	319 lb.	304 lb.	297 lb.
May, 1923	755 lb.	465 lb.	726 lb.	451 lb.
Increase	445 lb.	146 lb.	422 lb.	154 lb.
Bone meal ration ..	3 oz.	Nil.	3 oz.	Nil.

Post-mortem examination brought out the important fact that the carcases of the animals receiving the additional phosphorus in the form of bone meal had a higher proportion of their live weight in the form of butcher-dressed carcase than the others. They carried more meat and fat in proportion to skeleton and entrails, and the muscle fibres were more liberally interlarded with fat. It is obvious from these results that phosphorus was the limiting factor for the utilisation of those organic food constituents in the pasture which are transformed to meat and fat.

1. Animal showing typical symptions of "Nakuruitis."



2. Animal grazing on same pasture as No. 1, but receiving ad lib. supply of lick consisting of salt and iron oxide.



3. Showing the effect of bone meal and salt on the growth of cattle grazing on pastures markedly deficient in phosphorus.

(Above illustration taken from the *Journ. Dept. Agr., South Africa*, VIII, No. 5, 1924. The writer is indebted to Sir A. Theiler, Dr. H. H. Green and Dr. du Toit for permission to reproduce it here).

Another important fact brought out by these tests is that the amount of phosphorus required to prevent diseases which developed through lack of this mineral is not the optimum amount for growth. Some cattle were fed bone meal in just sufficient amount to prevent the onset of depraved appetite (osteophagia), while comparable animals were given five times as much. These South African workers give the following figures to illustrate the nature of the results obtained as estimated by increase in weight from January, 1922, to May, 1923.

TABLE IX.

	Group I. Control. (No Phosphorus.)	Group II. Sufficient Phosphorus to prevent Pica.	Group III. Additional Phosphorus.
Amount of bone meal fed (lb.) ..	Nil.	15	75
Gain in weight (lb.)	166	295	352

The amount fed to Group III was intentionally in excess of the requirements. It is possible, therefore, that an even better result would have been obtained with an optimum amount instead of an excess.

Tests with milch cows in the same phosphorus deficient area in South Africa, showed that the feeding of bone meal was accompanied by a 40 per cent. increase in the milk yield compared with controls receiving no bone meal.

Results in the same direction have been obtained both in Kenya Colony and in the West of Scotland in feeding sheep with small amounts of substances rich in the minerals deficient in the pastures. In the deficient areas in these districts, lambs of ewes, which had access to a mineral mixture, were heavier than those of control ewes grazing in the same pastures, and the fleeces of the ewes were from 5 to 10 per cent. heavier.

In the South African experiments it was noted that the calves of the bone meal fed cows were from 10 to 20 per cent. heavier than those of the controls. In a later paper by Malan, Green and du Toit[11] dealing with a continuation of these experiments, it is stated that " in general appearance and in weight the calves of the cows receiving bone meal showed a marked superiority over calves of control mothers and were much more uniform...... In general the character of the unweaned calves bears a definite relation to the extent to which the mother suffered from a-phosphorosis ". In the feeding tests with sheep in Scotland, referred to above, it was noted that the improvement in quality of the sheep receiving supplementary feeding making good deficiencies in the pasture, is more marked in the second generation. These preliminary observations in South Africa and Scotland suggest that the deterioration in size and quality of improved breeds which is commonly noted when they are put on poor pasture (p. 33) is due to a deficiency in the pasture, and could be prevented by appropriate supplementary feeding.

These results illustrate the fact that the disease is merely the extreme effect of the deficiency and that there may be a degree of deficiency, which, while not sufficient to cause disease, yet limits the rate of growth and the production of milk and wool. They also show that the methods taken to prevent disease in the highly deficient areas are likely to result in increased rate of growth and increased production if applied in any area where the proportion of constructive material is lower than in good pasture.

VI.—EFFECT OF DEFICIENCIES ON RESISTANCE TO DISEASES OTHER THAN SPECIFIC DEFICIENCY DISEASES.

It is now believed that in the case of many diseases due to invasion by micro-organisms, the condition of the animal itself is an important factor in determining whether the disease will develop and that even if it does develop, the condition of the animal will have an influence on the degree of severity of the attack. If this view, which has a great deal of evidence to support it, be correct, deficiencies in pastures would tend to predispose the grazing animal to a number of diseases in addition to the specific pathological conditions directly due to the deficiency.

In the work in Scotland it has been noted that in general the mortality in sheep is highest in areas where deficiencies in the pastures are most marked, and in tests there during the last two years the rate of mortality was lower in animals receiving supplementary feeding, which made good the deficiencies, than in control animals on the same grazing. In a recent private communication to the writer, Dr. du Toit[12], of South Africa, has stated that one of the most remarkable results being obtained in his tests, on the effects of the feeding of bone meal and salt, in the phosphorus deficient area, is the decreased mortality in the bone meal fed groups as compared with the controls.

In the South African work, it has been found that, in cattle on phosphorus deficient pastures, the inorganic phosphorus in the blood is low compared with that of normal healthy animals. A similar result has been noted in America.

These preliminary observations suggest the probability that deficiencies may not only be the cause of definite diseases of malnutrition, but may also, by affecting the composition of the tissues or the circulating fluids of the body, lower the natural resistance of the animal and so be predisposing causes of other diseases. The collected data so far, however, are too meagre to be more than an encouragement for further investigation.

Although in the past the attention of research workers has been so largely concentrated on diseases which are the result of extreme deficiencies, recent research work suggests that the most serious economic loss arises not from the deficiency diseases, which after all occur only in limited areas, but from the lowered rate of production and probably also from the increased susceptibility to diseases generally, which result from all deficiencies to an extent varying with the degree of the deficiency. It also looks as if the same means which had been found successful in the prevention of deficiency diseases can be used to increase production and improve the "constitution" of the grazing animal.

The amount of material which needs to be given to balance up the deficient pastures is comparatively small. It will be seen that there is little difference in the caloric value of good and bad pastures. The total metabolisable mineral matter is only about 6 to 7 per cent. of

the total dry matter in good pastures. In deficient pastures it is only a fraction of this which is lacking. Hence the amount which must be supplied is but a small fraction of the total food intake. The substances used to make good the major deficiencies are comparatively cheap, common substances such as bone meal, common salt and chalk. Hence the cost of supplying the deficient elements is low.

Our knowledge, however, is very incomplete with regard to the nature and extent of deficiencies in natural pastures in different districts. As will appear later, these vary, largely according to the nature of the soil and the climate. It is obvious that no single form of supplementary feed such as a " salt lick " or a " mineral mixture " of constant composition would meet the requirements in all districts or even in the same district at different seasons. At present there is a large amount of work being done in different parts of the Empire to determine the nature of the deficiencies and how best they can be made good.

Though supplying salt licks or mineral mixtures is a quick and cheap method of rectifying deficiencies in pastures, it is an artificial and only a second best method. Pastures deficient in minerals tend to be poor in other nutritional qualities. They tend on the average to contain more of the less easily digested fibre and less of the active living protoplasm, which is rich not only in minerals and protein, but also in other health factors. Further, the period of growth, during which pastures contain a large proportion of succulent leaf and stem, is shorter in poor pastures. Hence a mineral rich pasture is a better diet than a mineral poor pasture supplemented by a salt lick, however well the lick be adjusted to meet deficiencies. It is important, therefore, to study the factors upon which the mineral content of pastures depends.

VII.—FACTORS AFFECTING COMPOSITION OF PASTURES.

These factors can be classified roughly under the following headings :

Species of plants.
Seasonal variation and stage of growth.
Climatic conditions.
Composition of the soil.

Species of Plants.

Different species of pasture plants show natural differences in mineral composition, even when grown on the same soil and under the same climatic conditions. The most outstanding difference is that between legumes and grasses. The following table compares rye grass with clover, grown in the same field :—

TABLE X.

Percentages on Dry Matter.

	CaO.	P_2O_5.	Na_2O.	K_2O.	Cl.	SO_3.	Fe_2O_3.	Protein.
Rye grass ..	0·49	0·80	0·33	3·07	1·15	0·99	0·05	16·06
Clover	1·44	0·72	1·03	2·89	1·05	1·01	0·07	22·44

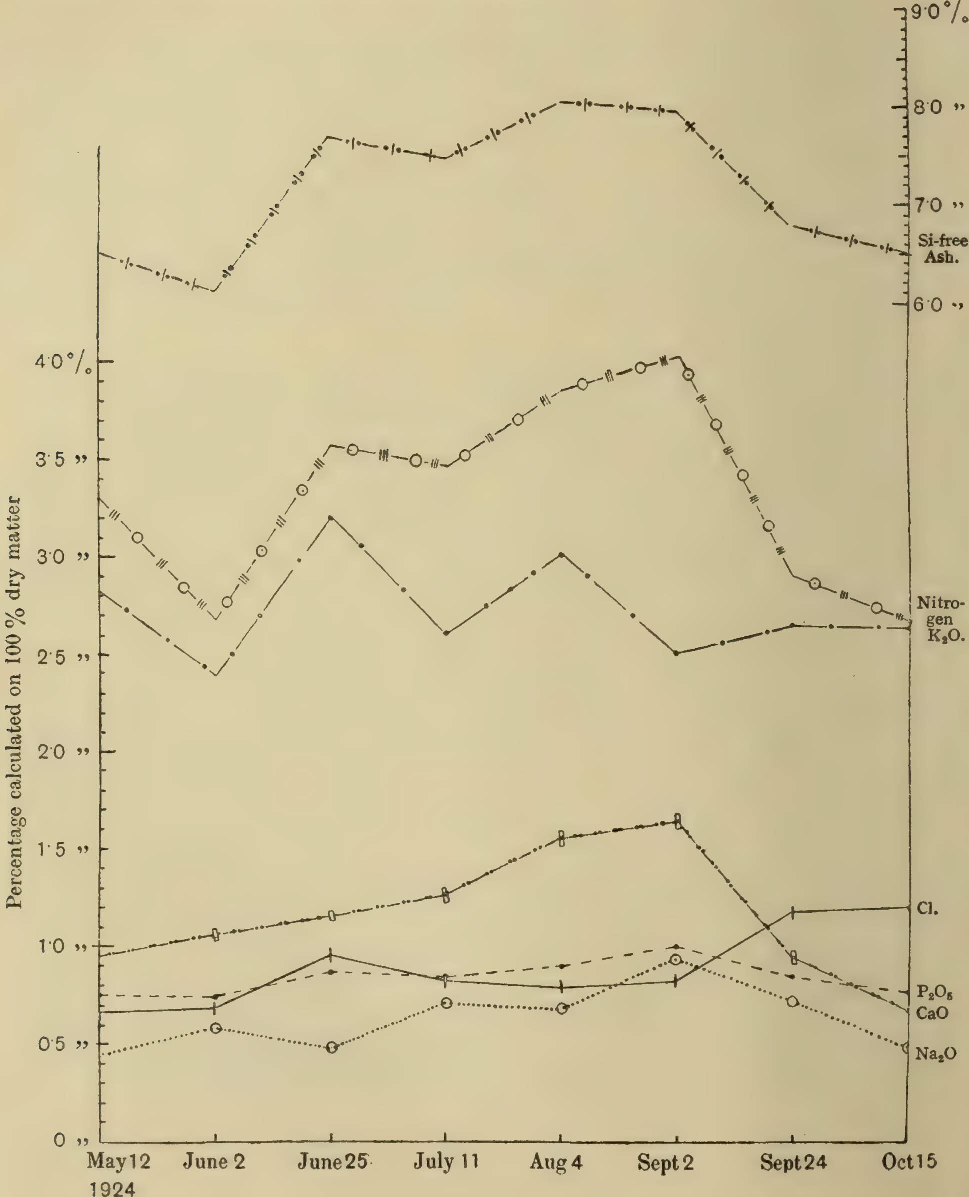
The legumes tend to be richer in both protein and minerals, especially in calcium. The grasses, however, are relatively richer in phosphorus than the legumes.

It is well known, that the addition of clover and other legumes to grasses, increases the value of the grazing. This is probably due to some extent to the fact, that the two together in the proper proportions make a well-balanced diet. An excess of legumes, however, might upset this balance by supplying an excess of calcium and probably also of protein in proportion to the other constituents, and it is doubtful whether a pasture consisting entirely of legumes would be as nutritious for any class of herbivora as a mixed pasture. It would be of interest to have some observations made on the relative value of pastures with different proportions of clover to determine the limit beyond which an increase of clover becomes detrimental. The proportion of clover can, of course, within limits, be regulated by management. Close grazing and certain kinds of mineral fertilisers promote a spread of clover. Nitrogenous manures on the other hand favour the growth of the grasses. The art of grassland management involves the manipulation of factors such as these.

The chemical composition varies in different strains of the same species of plants. By selective breeding it is possible to produce improved strains which are better " mineral catchers ". Valuable work in improving strains and in finding or breeding new types of plants more suitable for different districts and different climates is being done at the Plant Breeding Station at Aberystwyth and various other centres throughout the Empire.

Seasonal Variation and Stage of Growth.

The following graph shows the seasonal variation of protein and mineral constituents in samples collected at three-weekly intervals from May to October on a farm in Aberdeenshire. It will be seen that the protein and silica-free ash tend to rise to a maximum in the summer and decrease in the autumn.



It is most probable that the seasonal variation is associated not so much with the season as with the stage of growth of the plant, the mineral and protein content being highest when there is a maximum of leaf and stem rich in active protoplasm and a minimum of fibrous supporting material.

Climatic Conditions—Effects of Drought and Irrigation.

It is well known that the amount of sunshine, the temperature and the rainfall all affect the rate of growth and the rate of transpiration, and that the latter factor has an influence on the amounts of salts in solution brought in by the roots of the plant.

The factor which has been studied most is the effect of rainfall. It seems to be definitely established that in periods of drought the phosphorus content of the herbage falls markedly. Lewite[13] gives the following figures for analysis of hay from a district in Germany, showing that with a heavier rainfall the percentage of phosphorus was higher and that of calcium was lower.

	In 100 parts Dry Matter.		Rainfall.
	P_2O_5.	CaO.	mm.
1902	0·372	0·541	275·7
1904	0·222	0·784	118·3

Some very low figures for phosphorus have been obtained during dry seasons in South Africa. In some cases the percentage found has been below 0·1 per cent.

The effects of irrigation appear, as might be expected, to be opposite to those of drought. The phosphorus content rises, and, so far as figures are available, the calcium content appears to fall. This is shown by the following figures from Chavan[14], who analysed hay from unirrigated and irrigated meadows near Lausanne in Switzerland.

TABLE XI.

	Irrigated Meadows.	Dry Meadows.
	Per cent.	Per cent.
P_2O_5	0·729	0·457
K_2O	3·306	2·895
CaO	0·943	1·002
MgO	0·474	0·381
SO_2	0·649	0·682

The alteration in the mineral content of the herbage during drought, especially the marked decrease in the percentage of phosphorus, affords an explanation for the repeatedly noted fact that deficiency diseases are much more severe in dry years and in semi-arid countries, e.g. parts of South Africa and Australia (p. 8). The decrease in the percentage of calcium in heavy rainfall, though not so marked as the decrease in phosphorus in drought, may have a bearing on the composition of pastures in districts with a heavy rainfall such as the Western Highlands of Scotland. The soil in some of these districts is poor in lime, and Lewite has noted that the effect of excess of soil moisture on the calcium content of the herbage is greatest on a lime poor soil.

The application of fertilisers to soils seems to affect the rate of loss of water from the soil. It has been noted that in drought the pasture with a high percentage of mineral matter and, therefore, presumably growing on a rich soil, remains green longer in drought than the pasture with a low phosphorus content and, therefore, presumably grown on phosphorus poor soil. Further, the former responds to rain more quickly than the latter. At the Waite Institute in South Australia, it has been noted in pot experiments, that transpiration of water by pasture plants from phosphorus-poor soil is greater, in some cases to the extent of about 30 per cent., than that of plants grown in the same soil with super-phosphate added. It looks as if the enrichment of the soil conserved the soil moisture. If this result be confirmed in field plots, it will afford an additional reason for applying phosphates to phosphorus-poor soils in areas with a low rainfall. It is a result of great potential economic importance to the pastoral industry in semi-arid regions.

Composition of Soil—Enrichment by Top-dressing—Impoverishment by Depletion.

The researches of Lawes and Gilbert[15] showed that the mineral composition of the herbage tends to be a reflection of the available mineral nutrients in the soil. This is brought out very clearly in many experiments which have been done to test the effect of the application of fertilisers, the addition of which changes the composition of the soil. The following table shows the effects of the addition of phosphates and lime to four acre plots on a poor soil in a district in Australia (Richardson[16]).

TABLE XII.

Composition of Herbage. Percentage on Dry Matter.

Fertiliser applied.	Protein.	P_2O_5.	CaO.
No manure	9·13	0·27	0·60
Superphosphate	14·25	0·59	1·47
Superphosphate plus lime	13·75	0·46	1·44

It will be seen that the percentages of both phosphorus and calcium are about doubled in the herbage grown on the soil enriched by the fertilisers.

The percentage of protein is also increased by about 50 per cent., although no nitrogenous fertiliser was applied. Pastures deficient in calcium and phosphorus tended also to be deficient in protein (p. 10). It is evident that deficiency of protein is secondary to the deficiency of minerals. The atmosphere has an unlimited supply of nitrogen which, under the right conditions, can be absorbed into the soil and be available for the plant. The ultimate limiting factor for protein in the plant, therefore, is not the supply of nitrogen, but the supply of lime, phosphates and possibly other elements which promote soil and plant conditions favouring the absorption of nitrogen.

The effect of the application of the mineral fertilisers on the composition of the pasture is most marked on poor soils. This is well brought out in some tests carried out at the Rowett Institute. The following table (Godden[17]) shows the effect of lime and phosphates on (*a*) very poor moorland soil and (*b*) cultivated.

TABLE XIII.

Percentage on Dry Matter of Herbage.

Fertiliser applied.	Poor Moorland Soil. CaO.	Poor Moorland Soil. P_2O_5.	Cultivated Soil. CaO.	Cultivated Soil. P_2O_5.
Nil (control)	0·59	0·29	1·16	0·96
Lime	0·77	0·30	1·37	0·92
Superphosphate	0·94	0·71	1·16	0·93
Lime plus superphosphate ..	0·98	0·73	1·56	0·92

It will be seen that in the poor soil the addition of the phosphate markedly increased the phosphorus content of the herbage, whereas in the cultivated soil the phosphorus content of the pasture, which was already high, was not increased.

There are two factors concerned in this correlation between soil and herbage. A rich soil favours the spread of those plants which are naturally rich in minerals. Thus Richardson[16] in his tests found that the application of fertilisers altered the botanical composition, as is shown in the following table.

TABLE XIV.

Extracted from Richardson's Data.

	Percentage in Pasture.		
Fertiliser applied.	Grasses.	Clovers.	Weeds.
No manure	64·7	14·3	21·0
Superphosphate	18·0	74·8	7·2
Superphosphate plus lime	21·0	74·3	4·7

The great increase in the mineral rich clover would increase the average mineral content of the sward.

In addition to the alteration in the botanical composition the mineral content of the individual plants of whatever species is influenced by the composition of the soil. This has been shown in a systematic study by Godden[17], who used the same kind of seeds in

plots of soil of different composition. The plant tended to be rather richer in the mineral element in which the soil was richest.

Just as there is an equilibrium between the rate of growth and production of the animal and the composition of the herbage, there is a somewhat similar equilibrium between the chemical and botanical composition of the herbage and the nature of the soil. The nature of the soil has, therefore, an influence on the grazing animal. It is interesting to note that several expert stockmen have pointed out that the geological formation has an influence on the evolution of different breeds, e.g. Bakewell[18] (1808); Blacklock[19] (1838); McMillan[20] (1875); "Comet"[21] (1925).

Several earlier investigators had the idea that some pastures were of low feeding value on account of their poverty in mineral matter and that this poverty was a reflection of a similar poverty in the soil. Thus, for example, Wright[22] (1857) in discussing the necessity for bone-forming material says: "Where impoverished, ill-looking animals are found, there is probably a want of this invaluable ingredient in the herbage". McMillan[20] (1875) in a paper on "The Influence of Geological Formation on the Health Development of Sheep", says: "When sheep have to graze upon grass which does not contain all the earthy matters required, they will become poor in quality and predisposed to disease". Some of these early writers record the results of attempts to enrich the soil. Wright applied a dressing of 7 cwts. ground bones per acre and found that the land carried "one-half more stock combined with great improvement in the state of the stock themselves at the end of the summer".

The more recent work of Somerville[23] and his co-workers is on similar lines, though they did not concern themselves directly with the chemical composition of the pasture. They showed that the application of slag (i.e. a combination of phosphorus, calcium and other inorganic elements) resulted in the growth of a pasture which had a much higher feeding value; the live-weight increase on plots receiving basic slag being sometimes as much as six times as great as that on adjoining untreated plots. These tests, which began at Cockle Park in 1897, have been repeated at other English centres with equally marked results. In similar tests begun in Scotland in 1901 and carried on for ten years by Wilson[24] and Hendrick[25 26], the results were less striking, the difference being evidently due to the fact that in the Scottish soils on which the tests were made, phosphorus was not the limiting factor to the same extent as in the case of the soils on which the English tests were done.

The beneficial effect of the application of these mineral fertilisers was not due merely to an increase in the quantity of the herbage. Hendrick makes this clear. In discussing the seasonal differences in nutritive value of pastures in connection with these tests, he states that the differences were due not to increase in quantity but to the factors affecting the nutritive properties. Somerville also recognised that the improvement was in the quality of the pasture rather than in the quantity. He noted that animals on the improved pasture did better than animals on the unimproved, althought the latter were receiving concentrates in addition to the poor pasture. In later work by Richardson in Australia, the pastures were analysed, and the data showed that the increase in the feeding value was connected with an increase of calcium, phosphorus and protein in the pasture.

It is unnecessary to refer in detail to the general improvement which occurs in most pastures through an application of the proper mineral fertilisers. This method of treatment of pastures has in the past few years becomes established as a routine practice in good farming. It is a matter of common observation that the yield of the pastures and their carrying capacity are increased. In many cases the carrying capacity is doubled. This improvement has been effected not only in natural pastures but also on cultivated lands (Cruickshank[27]). The most extensive improvements, however, have been effected in the grazing lands of New Zealand, and in the Southern parts of Australia. In Australia the carrying capacity in some districts has been more than doubled and the rate of growth of the sheep has been increased, so that these improved pastures carry a larger framed sheep. Unfortunately the improvement of Australian pastures tends to be accompanied by a deterioration in the quality of the wool, the larger sheep on the improved pastures having a stronger wool than the smaller sheep on the poorer pastures. This is a problem urgently requiring further research. A beneficial effect similar to that obtained in the case of sheep in Australia has been found in the case of dairy cattle in New Zealand. In that Dominion, phosphatic dressings are extensively and regularly applied throughout the dairying areas, and this practice has materially aided in the maintenance of health and vigour in dairy cattle, in improving the average butter fat production per cow, and increasing the carrying capacity of the pasture (Reakes[28]). There is little doubt that within the next few years mineral fertilisers will be used in increasing

quantities with the object of increasing the carrying capacity of the pastures, and increasing the rate of production of the animals grazing on them.

The importance of the enrichment of the soil by the application of mineral fertilisers is now fully appreciated. Of equal importance, however, is the change in the other direction, namely the gradual impoverishment through the removal of animals and animal products without any compensating return to the soil. This process is going on in all pastoral areas where nothing is being done to improve or even maintain the quality of the pastures.

Richardson[16] has recently called attention to the effects of depletion in Victoria. He has estimated that the soil of Victoria has been depleted to the extent of about 360,000 tons of phosphoric acid during the last sixty years, through the removal of phosphates in the exported meat, milk and other animal products, and that nearly 2,000,000 tons of super-phosphate would need to be added to the pasture lands to restore them to the condition they were in about 1860. There is some evidence that the same process of depletion may be taking place in India, on account of the large export of bones which has been going on for many years. During the years 1920–1925 over 520,000 tons of bones have been exported without any compensating return being made to the soil. The figures for Victoria and India illustrate the extent to which soil nutrients may be removed from a country.

We have no analytical data comparing the composition of pasture of 50 years ago with those of to-day in the areas where we believe depletion is taking place. We do know, however, that in some districts the botanical nature of the herbage has changed and that the quality of the pasture has deteriorated. Accompanying this change there has been a deterioration in grazing stock. Richardson attributes malnutrition in stock in Victoria to deficiency of phosphorus, which has been accentuated by depletion. Munro[2] reports that in the Falkland Islands in the last 20 years the effects of depletion have become manifest in increasing difficulty in rearing lambs and in reduction in size in the progeny of imported horses.

The poorer hill grazings in Scotland are an example of depletion which has been going on for the last two hundred years. Generation after generation of sheep have been taken off the hills with little compensatory return. Accompanying the resulting deterioration of the pasture, the stock tend to be reduced in the rough hill grazings. The extent to which decrease of stocking has taken place in the

Highlands and Islands of Scotland during the last fifty years has been brought out in an enquiry instigated by Sir Robert Greig (1927). In the group of counties—Argyll, Inverness, Ross and Cromarty, Sutherland, Perth—i.e. those covering the greatest proportion of mountain and heath grazings of the mainland and the whole of the Hebrides, there has been a decrease of 11·5 per cent. in the number of cattle and 22·7 per cent. in the number of sheep compared with an increase of 11·2 per cent. in the cattle and 19·5 per cent. in the sheep for the remainder of Scotland. Figures are available for eight individual counties. The following table shows the increase or decrease in stocking in these counties :—

TABLE XV.

Counties.	Mountain and Heath Grazings (per 1,000 acres, crops and grass).	Percentage Increase or Decrease in Grassland (hay and grazing), excluding Mountain and Heath.	Percentage Increase or Decrease in Total Cattle.	Percentage Increase or Decrease in Total Sheep.
Sutherland ..	29,000	+40	− 38	− 32
Argyll ..	12,014	+19	− 13	− 38
Stirling ..	1,328	+20	− 1	− 6
Ayrshire ..	1,095	+ 7	+ 14	− 4
Forfar ..	811	+15	− 6	+ 48
Berwick ..	403	+35	+ 52	+ 37
Aberdeen ..	310	+18	+ 6	+ 72
Fife	75	+29	+ 9	+ 66

It will be seen that in the counties with the large areas of mountain and heath, even though apart from mountain and heath there has been an increase in the grassland, there has been a heavy decrease in the stock, whereas on richer lands, where better farming practices, including the application of manures and fertilisers, are in vogue, the carrying capacity is being increased.

The reduction of the stocks on the poor hill pastures, especially in the cattle, has allowed increasing amounts of herbage to grow up uneaten. In the autumn the fibrous, mineral-poor vegetation dies down

and forms a spongy mat which becomes water-logged. This mat slowly increases in thickness, separating the spring growth further and further from the true soil. This process of bog or peat formation is going on in many parts of the moors in Scotland at the present time. The depletion of the Scottish hills has been going on with increasing rapidity since the time when the produce of the animals, instead of being consumed on the land and, therefore, returned to the soil, began to be driven off to be consumed in the industrial areas. There are now districts in the Highlands which could not support populations which once lived there, even though the people were willing to accept the standard of living of their ancestors. It is a significant fact that Stornoway, in the Island of Lewis, is now supplied with milk from the rich lands adjoining the Moray Firth.

In most parts of the world, as for example in parts of Australia, depletion is associated not with excess of moisture, but with drought. In the areas of heavy rainfall, depletion favours the formation of a dense mat of fibrous material—the fore-runner of peat. In the semi-arid areas on the other hand, as depletion proceeds the vegetation tends to disappear, partly because as the soil becomes impoverished the pasture tends to react more slowly to whatever rainfall there is and partly because whatever vegetation exists is liable to get literally eaten out. The process tends towards a barren soil denuded of pasture.

This process of depletion is of great economic importance. It has not been sufficiently recognised that accompanying the movements of animal products there is a slow invisible flow of soil fertility. Every cargo of beef, mutton, milk products or wool, every ship load of bones, leaves the exporting country so much poorer, and unless measures be taken to restore to the soil the nutrients removed, deterioration of pasture with resulting deterioration of grazing stock and decreased production must inevitably follow.

The element in greatest demand, especially for the great pastoral areas with a low rainfall, is phosphorus and to some extent the future of animal husbandry in these countries depends upon an abundant and cheap supply of phosphates. It is possible that the Nauru Islands with their great deposits of phosphates will become of even greater economic and political importance than was thought to be the case when the mandate was given to Australia and New Zealand.

VIII.—APPLICATION OF KNOWLEDGE TO INCREASE PRODUCTION OF GRASSLAND PRODUCTS.

The recent advances in our knowledge of the chemical composition of pastures and the requirements of grazing animals for the different constituents found in them has given us a clearer conception of the *modus operandi* of the methods which in the past have been found successful in improving pastures. It also indicates the possibility of increased exploitation of pastures in the future. It will be of interest to consider, in the light of this knowledge, the experimental work being done with the object of increasing the yield of animal products from grasslands.

On high grade pastures, i.e. those which have been produced through cultivation of the soil and the sowing of grass seeds, large field trials are being carried out to test the effects of frequent top-dressing combined with close grazing by heavier stocking. Close grazing encourages the growth of the protein and mineral rich low growing clover plants which tend to be choked out when the grasses are allowed to grow long. It also helps to maintain all the plants at the early stage of growth at which they have the highest concentration of both proteins and minerals. This system, therefore, tends to prolong the period of the season during which the pasture is rich in constructive material and, therefore, well adapted to the needs of rapidly growing animals and milk cows. The application of nitrogenous fertilisers gives a stimulus to growth and is especially effective in bringing the grass out earlier in the beginning of the season and keeping it growing later in the end of the season, which further extends the period when the pasture is at or near its maximum feeding value.

The frequent systematic top-dressing restores immediately to the land all the lime, phosphates and other minerals which have been removed in grazing and so prevents even the beginning of depletion.

This intensive method of grazing increases the carrying capacity of the land and thereby, of course, increases the yield of animal products per acre. Further it maintains land in a high state of fertility suitable for giving a rich harvest if the necessity for cropping should arise.

On many soils it will be possible to maintain permanent pasture of the highest quality. On some soils it may be necessary, at intervals, to cultivate the land on account of slow progressive changes in its

physical composition. But there will be no need to follow a rotational system of cultivation merely for the purpose of ploughing in manure and sowing new grass seeds to renew the pasture on account of the fact that in the third or fourth year it has run out.

In Britain this intensive method of grassland treatment is in the experimental stage. Much more information is needed with regard to the amounts and kinds of fertilisers best suited for different types of soil. This information is now being obtained in field trials and costings are being done to show the relationship between the increased expenditure and the increased return in grassland products.

Associated with these experiments on intensive pasture production is the investigation on "grass cakes" which is being carried out at Cambridge University. These can be produced by drying and compressing pasture cut several times in the course of the season. The cakes form a better balanced ration for milk cows than hay, roots and concentrates which are usually fed in winter. Therefore, if they can be produced cheaply they will be of great value for winter feed both for maintaining a high level of production and for keeping the animals in good condition. The success of this method of fodder preservation depends on the cost of production. The investigation has resolved itself largely into an engineering problem.

But areas where intensive pasture cultivation is carried on form only a small proportion of the total grasslands of the Empire. In many of these other wider areas of natural pasture, top-dressing with phosphates is already increasing the carrying capacity and improving the quality of the stock. But although in a great many districts phosphorus is the limiting factor for soil fertility, it is probable that as the soil becomes rich in phosphates some other element may become a limiting factor. Indeed, it has been suggested that continuous application of super-phosphate may result in an excess of phosphorus in relation to other elements. This question is receiving consideration in New Zealand.

Another interesting question in connection with the application of fertilisers is the effect of the fertilisers on the transpiration of plants. The results of research at present being carried out at the Waite Institute in Australia, suggest that poverty of the soil tends to an excessive transpiration of moisture by the plant. The application of the right kind of fertiliser would, therefore, lead to the conservation of soil moisture—a question of great economic importance in semi-arid regions subject to occasional droughts.

There are large areas of natural grazings where even top-dressing is not economically possible. In these districts, supplementary feeding with substances to supply whatever is deficient in the pastures has been shown to lead to the elimination of deficiency diseases and also to increased production. This method is cheap and if successful the returns are immediate. But we need much more information with regard to the nature of the deficiencies in different districts and also the best methods of supplying whatever is found to be deficient. Work on these lines is being carried out in several parts of the Empire.

Further, large scale trials are also needed to test the effects of this supplementary feeding in preventing the deterioration of improved breeds when put upon inferior pastures and in increasing resistance to disease. These are being carried out both in South Africa and in Scotland. If the results continue to be positive there will be a need for research by physiologists, geneticists and immunologists on fundamental problems which, if solved, will have a very important bearing on the whole question of the susceptibility to disease both in human beings and in farm animals.

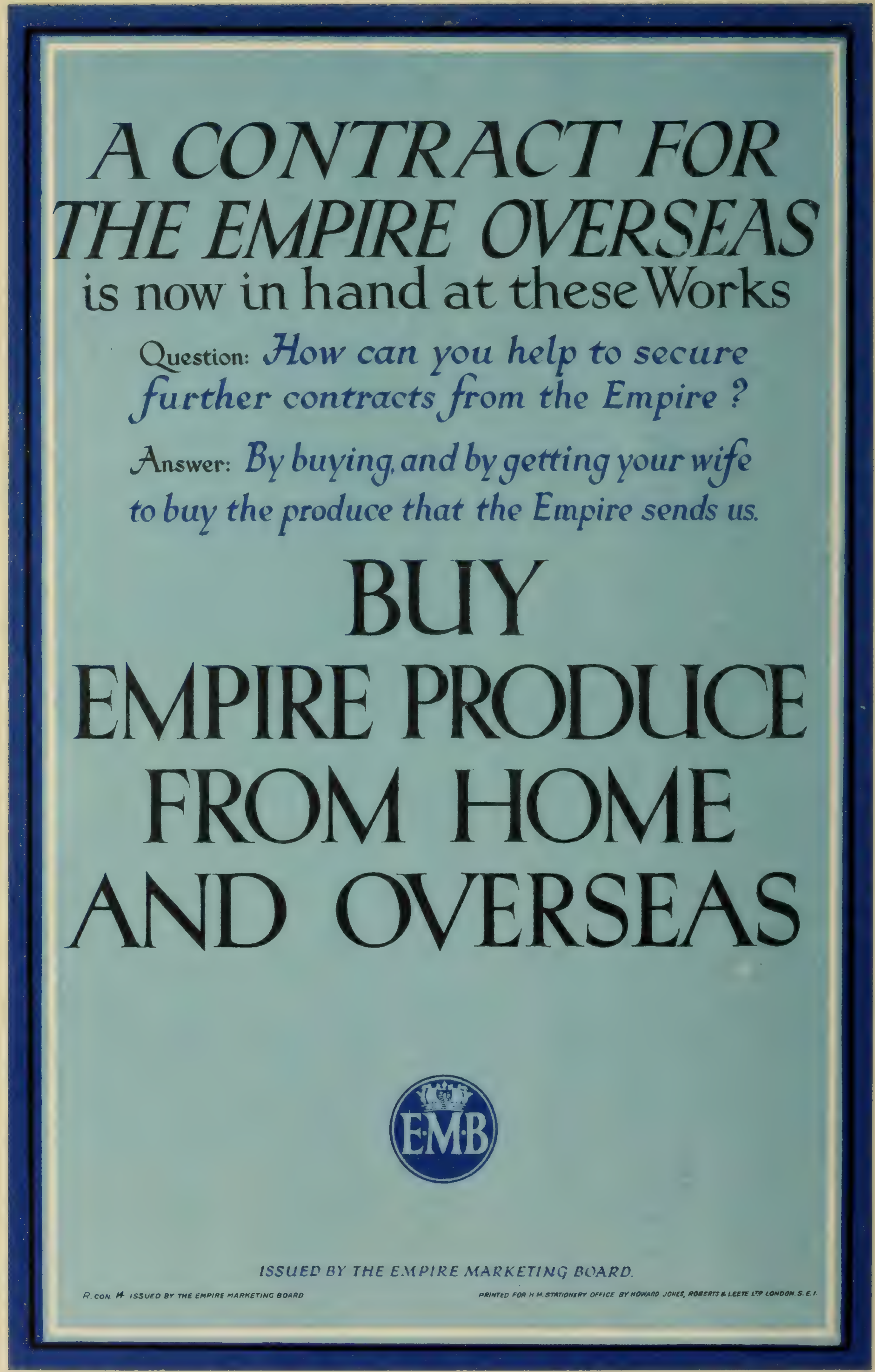
All these lines of investigation are being extended and intensified not only in Great Britain, but also in overseas parts of the Empire. Indeed, in some of the Dominions the research is in advance of that in the older established institutions in Great Britain. Fortunately there is a free though informal exchange of information between groups of workers in different parts of the Empire and the next few years are likely to see a considerable extension of knowledge which will enable us to adjust the food of the grazing animal more closely to its requirements.

Even though there is still so much more information urgently needed, the scientific information we already possess warrants the belief that the carrying capacity of pastures can be greatly increased and the health and quality of animals grazing on poor pastures can be much improved. It is probable that the total production of the grazing lands of the world can be doubled. This would, of course, mean enormous increase in the primary necessities, i.e. the world's real wealth. Where, however, we are dealing with natural processes where the cycle is completed only once in a year, and the life cycle of the animal is several years, the experiments designed to yield the information which can be applied in practice require several years before the economic results are demonstrable. It is in these experiments, testing and applying our acquired knowledge, that the main research effort throughout the Empire is now being concentrated.

IX.—REFERENCES.

1. P. J. du Toit : Official Report to Colonial Office, 1927. Quoted by permission.
2. H. Munro : Report on Falkland Islands, 1924.
3. W. Godden : *Journ. Agric. Sci.*, XVI ; 78–88.
4. T. W. Fagan and R. E. Evans : *Welsh Journ. Agric.*, 1926 ; II ; 113–116.
5. Klimmer and Schmidt : *Monats. f. Tierhk.*, 1906 ; XVII ; 481–517.
6. A. Theiler, P. R. Viljoen, H. H. Green, P. J. du Toit, H. Meier and E. M. Robinson : 11th and 12th Reports of Director of *Vet. Ed. and Res.*, 1927, Pt. II ; 1243, 1358.
7. M. Henry : *Veterinary Journ.*, 1915 ; XXII ; 62–72.
8. C. J. Reakes and B. C. Aston : *N.Z. Journ. Agric.*, 1919 ; XVIII ; 193–197.
9. B. C. Aston : *N.Z. Journ. of Agric.*, 1924 ; XXVIII ; 215–238, 301–308, 381–390.
10. A. Theiler, H. H. Green and P. J. du Toit : Union of South Africa : Dept. of Agric., " Phosphorus in the Live Stock Industry." Reprint No. 18, 1924.
11. A. J. Malan, H. H. Green and P. J. du Toit : *Journ. Agric. Sci.*, 1928, XVIII, 369.
12. P. J. du Toit : Private communication.
13. M. Lewite : *Mitt. d. Landw. Inst. d. Univ., Leipzig*, 1907 ; VIII ; 69–112.
14. Paul Chavan : *Annuaire Agric. de la Suisse* ; 1906 ; VII ; 1–13.
15. J. B. Lawes and J. H. Gilbert : *Philo. Trans.*, 1900, Ser. B ; 139–210.
16. A. E. V. Richardson : *Victoria Journ. of Agric.*, 1924 ; XXII ; 193–207, 257–270.
17. W. Godden : *Journ. Agric. Sci.*, 1926 ; XVI ; 101–102.
18. Robert Bakewell : Observations on the Influence of Soil and Climate upon Wool : London, 1808.
19. Ambrose Blacklock : A Treatise on Sheep, 1838 ; 228.
20. John McMillan : Trans. High. and Agric. Soc., 1875 ; VII ; 91–104.
21. " Comet " : *The Pastoral Review*, 1925 : XXXV ; 983.
22. W. Wright : *Royal Agric. Journal*, 1858 ; XIX ; 511.
23. Wm. Somerville : Min. of Agric. Misc. Public, 1921 ; No. 30.
24. D. Wilson : Trans. Highland and Agric. Soc., 1905, Ser. 5 ; XVII ; 271.
25. J. Hendrick : Trans. Highland and Agric. Soc., 1908, Ser. 5 ; XX ; 269.
26. J. Hendrick : Trans. Highland and Agric. Soc., 1911, Ser. 5 ; XXIII ; 190.
27. James Cruickshank : Trans. Highland and Agric. Soc., 1925, Ser. 5 ; XXXVII ; 23.
28. C. J. Reakes : Private communication.

Note.—A fuller account of the subject dealt with in this pamphlet is given in " Minerals in Pastures and their Relation to Animal Nutrition " (Lewis, London.)



Miniature contract poster issued by the Empire Marketing Board to factories in the United Kingdom (see page 24).

E.M.B. 19.

EMPIRE MARKETING BOARD

MAY 1928 to MAY 1929

JULY 1929

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any bookseller.

1929.

Price 1*s.* 0*d.* Net.

70-221-19.

TABLE OF CONTENTS.

(36805) Wt. P132/597/71 15,000 7/29 Harrow G.3 A 2

PROGRESS IN EMPIRE MARKETING.

THIS is the third Annual Report of the Empire Marketing Board. Two years ago, an account was published of how, in the less than twelve months of its active existence, the Board had begun to attack the task with which it had been entrusted. Last year, progress was recorded both in the intensity and in the diversity of the Board's activities. The present Report carries the story a stage further.

The duty placed upon the Empire Marketing Board by Parliament is to further the marketing in the United Kingdom of Empire products, including home agricultural produce. In pursuance of this duty, and in accordance with recommendations made from time to time by the Imperial Economic Committee, the Board's funds have been devoted to scientific research, economic investigation and publicity. Grants under the first of these headings are designed to help in increasing output, improving quality and decreasing wastage in the Empire's production. The immense and growing power of science to help the producer had not in the past been so thoroughly mobilised within the Empire as elsewhere in the world. The Board has, therefore, found many opportunities for financing scientific research of urgent importance to Empire Marketing. Grants under the second heading, economic investigation, have helped to keep producers, scattered over the Empire, in closer and more intimate contact with the needs and tastes of their wholesale and retail customers in the United Kingdom. They have, further, been devoted to throwing light on what may be termed the general problems of orderly marketing, which present themselves with such practical insistence to all engaged in Empire trade. Lastly, the Board's publicity has aimed at turning the thoughts of the home public to the theme of Empire buying.

Progress in each of these departments of the Board's work is summarised in the respective sections of this Report. The subjects thus dealt with are dissimilar, but they are given unity by the single purpose which has actuated the Board throughout—the increased sale in this country of commodities produced within the Empire at home or overseas. The consequences of such an endeavour over so wide a field cannot be isolated from the effects of other and

independent causes. It can, for instance, be shown that certain imports from Empire sources have in the last two years broken all previous records. But even if it is suggested that the Board has been a factor in this, it would evidently be impossible to measure, even approximately, the extent of its influence.

Growth of Empire Resources.

Nevertheless, the remarkable increase which has taken place in trade within the Empire in a very brief period is worth considering, for it directly affects the work of the Empire Marketing Board. The newness of many of the great exporting industries of foodstuffs and raw materials in the oversea Empire is not, perhaps, adequately appreciated. Every one of the Dominions and many of the Colonies have advanced within the last fifty years from a relatively modest position into that of important contributors to and purchasers in the great markets of the world. There has been an extraordinary development of the Empire's resources even since the beginning of the present century.

A survey confined only to the leading exports shows that Australia's shipments of wool have risen in this period from slightly over 500 million lb., to about 800 million lb., and her exports of wheat from half a million tons to two million. Canada's wheat exports have grown from about a quarter of a million tons to approximately seven million tons, and her exports of newsprint from next to nothing to two million tons. New Zealand's principal exports are wool and dairy produce ; the first has gone up from under 150 million to over 200 million lb., and butter from less than a quarter million, and cheese from 100,000 cwt. to nearly one and a half million cwt. in each case. In the Union of South Africa shipments of wool have risen from 90 to 260 million lb. Newfoundland has developed since the beginning of the century, an export trade in paper to the annual value of £2½ million. India, which cannot, of course, be compared with the Dominions for newness, nevertheless shows a similar advance. Exports of nearly all her numerous products have shown progress in the present century. Raw cotton, her main export, has increased from 400 million to nearly 1,500 million lb. last year and tea from 190 million lb. to 360 million lb.

In the Colonies an even more marked development has occurred. Cocoa exports, for instance, have risen from less than half a million to 110 million lb. in Nigeria, and from less than one and a quarter

million to 490 million lb. in the Gold Coast. Exports of rubber from British Malaya have grown from nothing to about 370,000 tons, although some part of the rubber exported has its origin outside British territory. Tea from Ceylon has gone from 140 million to 228 million lb., rubber from 73 cwt. to one and a quarter million cwt., and copra from less than half a million to two million cwt. Bananas from Jamaica ($8\frac{1}{4}$ million to 17 million bunches last year) may be quoted as a further instance.

Range of Empire Supplies.

The development of the natural resources of the oversea Empire is thus being carried out with steady effectiveness. The significance of this to people in the United Kingdom may be seen more vividly, perhaps, from another angle. The range of Empire products available in this country is year by year spreading. A revolution in Empire supplies has happened within the lifetime of those who are now barely middle aged. Memories are short in such matters and this revolution has hardly been noticed by the general public which has been so considerably affected by it. An article, not to be found in the land yesterday, appears as a curiosity and a luxury in a limited number of shops to-day, and comes down within reach of everybody to-morrow. But its former rarity is quickly forgotten and the new contribution to the variety of diet (and often also to health) is accepted without curiosity. That this should be so is natural. The additions made and being made by the Dominions and Colonies to our supplies deserve, however, to be emphasised in any consideration of the progress of Empire marketing.

Two generations ago, the United Kingdom derived only a very limited range of its requirements from oversea parts of the Empire. The fiftieth anniversary of the first shipment of frozen meat from Australia will take place towards the end of this year, while New Zealand's meat trade only began in the 'eighties. Fifty years ago only small quantities of butter and cheese came from the Southern Dominions ; the tea industry of Ceylon was no more than a few years old ; Canada had not yet begun to export apples, and no pears, plums, grapes, or peaches from South Africa and no apples or pears from Australia had reached this country. Rubber from Malaya, bananas from Jamaica and cocoa from West Africa were equally unknown. A quarter of a century later, in 1904, these products had all appeared on the United Kingdom market ; some of them, such as frozen meat

and dairy produce, had become firmly established, others were in their infancy. But there were still hardly any Australian currants or raisins, no New Zealand apples or pears, no South African oranges or grapefruit and no Kenya coffee. Year by year the gaps were filled up. But as recently as the end of the war there were no eggs from the Southern Dominions and scarcely any home produced beet sugar or canned fruits. In the last two or three years cigarettes made from Rhodesian tobacco have become familiar in our shops, cigarettes from Cyprus and Mauritius have been obtainable and canned fruit from Fiji, chilled salmon from Newfoundland and grapes from Palestine have, for the first time, been shipped to this country. Nor has this steady spreading of the range of Empire supplies ceased. New experiments in production are constantly reported and experimental consignments from many and scattered parts of the Empire give promise of an expansion in the future not less notable than in the past.

Recent Records.

High record shipments of various Empire grown foodstuffs have been achieved in this same brief period of two years. Australian sultanas and raisins imported in 1927 were 160,000 cwt. greater than in any previous season, while Australian wine more than doubled its previous highest figure. Severe frosts towards the end of 1927 lowered these imports in 1928, but Australian apples, pears and canned fruit all made records. Imports of frozen lamb, frozen pork and cheese from New Zealand in 1927 reached higher points than ever before, but in the cases of the first two were surpassed in 1928, while butter and cheese came respectively within two and three and a half per cent. of the record, and apples and pears both established new records. Shipments of oranges, grapefruit, peaches, grapes and wine from the Union of South Africa were all higher in 1927 than ever before. In 1928 grapes, oranges and grapefruit declined slightly, but were larger than in any year before 1927, while pears, raw sugar and wine all made records. Wheat and tobacco from Canada, coffee from East Africa and tobacco from Rhodesia are other commodities shipped to this country in 1928 in greater quantities than in any earlier year.

Such figures suggest that the marketing of Empire produce is being actively pursued in this country. Many agents, some of them outside human control (the weather, for instance) have intervened. But one conclusion may safely be drawn. The tide of Empire trade is flowing

strongly. The Dominions and Colonies are able to supply more and more of the needs of the United Kingdom and, in return, the United Kingdom is finding in the oversea Empire a growing demand for British goods. Already, with many of the Dominions and Colonies only on the threshold of their economic manhood, the oversea Empire, while it comprises only one quarter of the world's surface and population, absorbs nearly half the exports of the United Kingdom.

The Empire Marketing Board has found in this active, stirring world of Imperial trade many new objectives in the last year towards the attainment of which its funds might properly and usefully be employed. It is naturally best known to the public through its publicity work, particulars of which are given in the body of this Report. But its other activities have been no less vigorously pursued.

These, seen as a whole, may be defined as the making possible of an Empire-wide effort in scientific co-operation. Such hopeful developments of the last year as the establishment of eight new Imperial scientific Bureaux, jointly financed by the Governments of the Empire, and the appointment of the Colonial Advisory Council of Agriculture and Animal Health show how strongly the tide is flowing in favour of co-operation. Scientists and economists can between them offer four main contributions towards the furtherance of Empire marketing. First, they can help to develop to the full the at present barely tapped natural resources of the Empire. Secondly, they can help to render production as economical as possible by reducing waste in the field, in transit and in store. Thirdly, they can help to ensure that regularity of supply and uniformity of quality which are two essentials of progressive modern marketing. Lastly, they can provide knowledge, on the one hand, of crop prospects and general trade conditions in any producing industry and, on the other hand, of the special demands and preferences of the consuming public and of the traders through whom that public is reached. All the Board's expenditure on research and on economic investigation serve one or more of these ends.

It is essential in such work to take long views ; the prizes at stake are tremendous and, while the trend of trade cannot be changed in a day, there is no discoverable limit to the rewards that may fall to wisely directed research and well planned economic organisation. Certainly no industry that seeks to hold its own and still more to advance under the prevailing conditions of world competition dare turn its back on the scientist or the economist.

In conclusion, it need only be added here that the Board has been encouraged by the evidence it has received from official and from commercial sources that its work is considered useful by those who may be termed its clients, that is, by the producers of the Empire at home and overseas.

I. SCIENTIFIC RESEARCH.

IT would be impossible to describe in detail, except between the covers of a bulky volume, all the lines of scientific enquiry that are being followed with assistance from the Empire Marketing Fund. A general indication merely is given in this section of the way in which the Board is working. The succeeding paragraphs draw attention to some of the outstanding work in progress and should be read only in conjunction with the full list of grants given in Appendix II.

The year under review has seen schemes, previously launched, actively carried forward and new schemes begun. The policy of attracting, wherever practical, contributions from interested governments and outside bodies towards investigations financially helped from the Board's fund has been adhered to with satisfactory results. The sums contributed in this manner from other sources now amount to over £500,000, exclusive of the £700,000 offered by the International Education Board (Rockefeller Foundation) to Cambridge University.

The Board's grants cover many and diverse fields of enquiry and are being expended in widely scattered areas of the Empire. Workers are now active at its charges in the home country, in all the Dominions and in many Colonies. The main research centres in the United Kingdom and in Northern Ireland, outstanding institutions in the Dominions like the Waite Institute in Australia, the Onderstepoort Veterinary Research Station in South Africa, the Cawthron Institute in New Zealand and the Ontario Agricultural College, Guelph, and the University of British Columbia in Canada, and the University College, Dublin, are all co-operating. The Imperial College at Trinidad, which serves as a training ground for scientists who go out into every corner of the tropical Empire and as a centre of research, has been extended, while assistance has been given in restoring the Amani Institute in Tanganyika to its full measure of activity.

Specialists have been enabled, wherever the desirability has arisen, to make oversea journeys and the results of their investigations have been brought before producers and others who are affected. (*See*

page 14 "Scientific Travellers.") The policy of publishing reports of scientific and economic value has been continued. (*See* Appendix IV.)

The Pastures of the Empire.

The researches, described in the last Report, have been extended. A series of experiments is being undertaken in Kenya and in Scotland, to test more fully the results so far secured, by feeding to animals small amounts of substances which are deficient in the pastures on which they graze.

As a result of these researches, conducted simultaneously in many parts of the Empire into the chemical composition of pastures, a problem of the first magnitude is now being seen as a whole.* There is still much more information needed, but that already collected warrants the belief that the carrying capacity of pastures can be greatly increased and the health and quality of animals grazing on poor pastures can be improved. This work, moreover, suggests deductions of great value to human health and links up with much of the new work on the influence of foodstuffs on our whole resistance to disease.

The necessary lines of investigation are being extended and intensified not only in Great Britain, but also in oversea parts of the Empire. There is now a free exchange of information between groups of workers in different parts of the Empire, and it is estimated that the next few years are likely to witness a considerable extension of knowledge which will enable livestock farmers to adjust the food of the grazing animal more closely to its requirements. As, however, the problem concerns natural processes which must inevitably take several years to complete, demonstrable economic results cannot be expected to follow immediately from the experiments. It is on these experiments, testing and applying the knowledge acquired, that the research work on pastures throughout the Empire is now being concentrated.

Veterinary Research.

The most interesting development of the year in this field is the agreement by the Government of the Union of South Africa that the scope of their Veterinary Research Station at Onderstepoort, Trans-

---

* "The Composition of Pastures." Dr. J. B. Orr. E.M.B. 18. H.M. Stationery Office, London. (9*d*. net).

vaal, shall be extended in order to serve the needs not only of South Africa but of other states and territories within the Empire. The Board has approved a grant towards this purpose.

The Onderstepoort station, which has hitherto been maintained on an ample scale by the Union Government, has won for itself an outstanding reputation in world veterinary science. Its new status should lead directly to the intensified investigation of such problems as East Coast Fever and tse-tse fly control and to the granting of increased facilities for the training of veterinary workers from other parts of the Empire. The whole question of resistance to disease is also under active review at this station.

Entomology.

While several relatively lesser lines of research are being carried out in the field of economic entomology, two schemes of paramount importance are in hand.

First, the proposals (mentioned in the last Report) that the Board should co-operate with the Commonwealth Government of Australia in establishing an entomological division at Canberra have been approved. In common with every other part of the Empire, Australia suffers heavy losses every year from insects and weeds. The Commonwealth Council for Scientific and Industrial Research has been greatly impressed by the urgency of this problem and is organising an attack upon it on a large scale. Central laboratories are being erected at Canberra and field stations established in the various States. Dr. R. J. Tillyard, F.R.S. (formerly director of the Entomological section of the Cawthron Institute) has been placed in charge and the Empire Marketing Board is collaborating with the Australian authorities in a campaign that may be expected ultimately to yield results of interest to many parts of the Empire.

Secondly, the Farnham House Laboratory for breeding beneficial parasites, established by the Imperial Bureau of Entomology as the result of a grant from the Empire Marketing Board, has in the past year raised and shipped consignments of insects to many parts of the Empire. This laboratory now represents the largest scale application in the Empire of the principle of biological control of insect pests, and from it insects have been sent out in response to requests from Canada, New Zealand, Australia, South Africa, Kenya, the Falkland Islands and different parts of England.

Three Australian scientists from the Commonwealth Department of Entomology are at present carrying out research at the laboratories under the Superintendent, Dr. Thompson, who is himself a Canadian. Dr. Myers, of the Farnham House Staff, has gone to the West Indies to study tropical parasites, and he will organise shipments of beneficial insects between the various islands and British Guiana. At the same time the possibilities are being explored of conveying a parasite from the Sudan to Barbados, with Farnham House as a transmitting centre.

Mention should also be made under this head of the valuable investigations being carried out at the Cawthron Institute in New Zealand.

Grant to Cambridge University.

The Board has made a grant of £50,000 to the University of Cambridge towards the sum required to enable the conditional offer of £700,000 from the International Education Board (Rockefeller Foundation) to be accepted. A grant of £50,000 has also been promised from the Exchequer. The total cost of the developments planned at Cambridge is £1,195,000. Extensions are contemplated in the spheres of agriculture, biology and biophysics and the full scheme will include the building of a new University library.

The Board's grant is to be devoted to the development of research in agriculture and in the sciences upon which agricultural research depends. The project is regarded as offering an unequalled opportunity of providing for the advancement of science in its application to agriculture and of thereby directly assisting all parts of the Empire.

Low Temperature Research.

Since the issue of the last Report work in this essential field has been extended. The Cambridge Low Temperature Research Station is continuing its investigations into the effect of cold storage on the structure of tissue muscle and fat in meat and into the respiration of apples and other fruit. Close liaison is also being kept up with the Board's fruit inspectors (*see* page 19) at Liverpool and London. Similarly contact is preserved with the Long Ashton Horticultural Research Station whither fruit, grown under different conditions, is despatched and its keeping qualities examined. Further enquiries will be conducted at East Malling, where an experimental store on

a semi-commercial scale is being erected, under the same scientific control as the Cambridge station, at the charges of the Empire Marketing Fund.

Finally, the cold storage plant, referred to in the last Report, has now been erected at the Imperial College of Tropical Agriculture, Trinidad, and will be used in experimental work on the transport problems of bananas and other tropical fruits.

Scientific Travellers.

The value of personal intercourse between research workers scattered over the Empire but engaged on the same lines of investigation has from the first been recognised by the Board. Equally the Board has felt that experts should, wherever possible, be enabled to visit those parts of the Empire which are in special need of their scientific advice. The making of a grant to the Royal Botanic Gardens, Kew, mentioned in the last Report, has permitted a number of such journeys to be undertaken. Dr. A. W. Hill, the Director of the Royal Botanic Gardens, completed in the period under review his tour of Australia, New Zealand, the Straits Settlements, the Federated Malay States and Ceylon, where, at the request of the Governments concerned, he reviewed botanical institutions and advised on problems of economic botany. Major Chipp, the Assistant Director at Kew, visited Cyprus and the Sudan to report on general agricultural conditions and to establish liaison between workers. Mr. H. C. Sampson, economic botanist at Kew, having previously visited British Guiana, the Windward and Leeward Islands, Barbados and Trinidad, undertook a tour of British Honduras. He completed a survey of the agriculture of the Colony and made certain recommendations which have been published by the Board.* Dr. Orr, Director of the Rowett Research Institute, Aberdeen has travelled in connection with his investigations into questions of pasturage through Australia, New Zealand and Canada. Dr. J. E. Nichols, of the British Research Association for the Woollen and Worsted Industries, Leeds, is now engaged on a tour of the Dominions to enquire into problems of wool production. Professor H. Clark Powell has completed his tour of the citrus-growing areas and his report has been published by the Board.† Other scientific travellers,

* "Report on Development of Agriculture in British Honduras." H. C. Sampson. E.M.B. 16. H.M. Stationery Office, London. (1*s*. 6*d*. net).

† "Grape Fruit Culture in the British West Indies and British Honduras." Professor H. Clark Powell. E.M.B. 13. H.M. Stationery Office, London. (1*s*. net).

whose journeys have been facilitated by assistance from the Board, are Sir Robert Greig to Canada, Mr. C. Darlington, of the John Innes Horticultural Institution, and Dr. J. M. Cowan, of the Royal Botanic Gardens, Kew, to Iraq and Persia, Mr. C. W. Wardlaw, Plant Pathologist at the Imperial College of Tropical Agriculture, to the banana growing areas of the West Indies and Central America, Mr. H. C. Trumble, of the Waite Institute, University of Adelaide, to Palestine and North Africa on questions of sheep raising and pasture problems and Mr. W. J. Megaw of the Northern Ireland Ministry of Agriculture to advise on flax production in Cyprus.

II. ECONOMIC INVESTIGATION.

The Imperial Economic Committee has noted in several of its Reports the importance to oversea producers, as well as to producers and consumers at home, of a scientific study of economic conditions in relation to the requirements of the United Kingdom market. The Board has always shared the view of the Imperial Economic Committee on the subject, but has felt the lack of instruments ready to hand for prosecuting these researches on a considerable scale. As the work was thus distinguished from activities in regard to Scientific Research and Publicity, in the case of which existing agencies could to a large extent be employed, the Board has proceeded cautiously and experimentally. This qualification does not apply to the study of the marketing arrangements of home agricultural produce where the existing Agricultural Departments of the three home countries were in a position to develop quickly work begun before the Board's appointment ; and some account is given below of the grants made by the Board for this purpose, and the manner in which they have been employed. But no such agency was available in the case of oversea Empire produce. In that field the Board's experimental work has developed satisfactorily, and it is possible this year to give a fuller account of the programme on which the Board is working. Any such account should be prefaced by a recognition of the valuable work of the Imperial Economic Committee, whose reports upon particular commodities have in this and in other respects laid the foundations for their subsequent and continuous study by the Board. These reports have been rendered widely available by a contribution from the Empire Marketing Fund, which has enabled them to be sold at popular prices.

Agricultural Economics Committee.

As mentioned in last year's report the Board appointed a special Agricultural Economics Committee to advise them. This Committee has advised the Board, not merely in the field of the economics of production but also, if more generally, in the field of marketing of agricultural products. Under its auspices a memorandum on the Survey Method of Research in Farm Economics, prepared by Mr. J. P. Maxton of the Oxford Agricultural Economics Research Institute, has been published and circulated overseas. The Committee has emphasised the importance of improving the agricultural statistics of the Colonial Empire and has drawn special attention to the proposed World Census of 1930 to be conducted under the auspices of the International Institute of Agriculture. In view of the difficulty of collecting data relating to the area and production of native crops and the number of live stock in tropical colonies it is noteworthy that in more than one Colony the statistical staff has recently been strengthened and steps have been taken to make the official estimates more reliable.

An interesting departure in the study of the problems of retail distribution is the co-operation effected with the Economics Departments of certain Universities. In London, Liverpool and Leeds investigations are being carried out by trained economists in this new and promising field. The association of University Professors or lecturers with the detailed study of retail trade holds out promise of fruitful results leading to greater efficiency in distribution and a clearer understanding by retailers themselves of the economic aspects of their business problems.

Chair of Imperial Economic Relations.

The Board has approved a grant for the establishment of a Chair of Imperial Economic Relations at the London School of Economics in the University of London. The new Chair will, it is believed, provide an authoritative centre for the study of the economic problems which confront those engaged in the development of Empire trade and production. It should also increase the supply of trained economists qualified to undertake practical economic research along lines calculated to be of direct benefit to the marketing of Empire produce in the United Kingdom.

Statistics and Market Intelligence.

The Board's work in this field has embraced on the one hand the preparation of surveys of the world production and prospects of certain commodities and on the other the regular issue of market intelligence in respect of certain commodities.

A statistical survey of the world position as regards the production and consumption of oranges has been issued.* A similar survey of cocoa is in advanced preparation and other surveys are being undertaken. The Weekly Fruit Intelligence Notes issued by the Board have been continued and enjoy a wide circulation amongst producers and traders. A similar service for butter, eggs and cheese, recommended by the Imperial Economic Committee, has recently been started. These services supply weekly figures of shipments, arrivals at ports and forecasts of future supplies ; and the Board has set on foot and hopes to carry to successful completion a movement for the voluntary publication of stocks of dairy produce and fruit in cold store, to which considerable importance is attached by oversea bodies responsible for marketing Empire products in the United Kingdom.

The Marketing of Home Agricultural Produce.

In the previous Report, an account was given of the work undertaken by the Ministry of Agriculture and Fisheries with the aid of a grant from the Empire Marketing Fund for the improvement of marketing methods in England and Wales. During the last twelve months very material progress has been made.

As was shown in the last Report, the Ministry is pursuing a consistent and logical policy in dealing with this vital subject. The programme falls roughly into four stages—investigation and report, practical demonstration, demonstration under commercial conditions and the application of reforms to the ordinary operations of trade. The results of investigations are published in the "Economic Series" of Reports, (issued at a very low price) and in free Marketing Leaflets. The most recent knowledge on practical questions of marketing is thus made readily accessible to producers and distributors. Up to 30th April, 1929, 20 Reports in the "Economic Series" had been issued and nearly 70,000 copies sold. 420,000 Marketing Leaflets had been distributed. Grants have in addition been made to various research institutes for carrying out certain detailed enquiries.

* "Oranges : World Production and Trade." E.M.B. 15. H.M. Stationery Office, London. (1*s.* net.)

The policy of giving practical demonstrations relating to marketing reform at Agricultural and Horticultural Shows all over the country has been continued and extended. The following commodities have been or are being dealt with: eggs, poultry, fruit, glasshouse produce, potatoes, pigs, cattle and cereals.

Grants have been made to packing stations where new ideas are tested out under the stress of commercial conditions. The value of these grants has been established and the practice is being extended.

The most important development of the year has been the introduction of the "National Mark" scheme. The Agricultural Produce (Grading and Marking) Act, 1928, empowers the Minister of Agriculture to make Regulations defining standard grades for any agricultural produce, prescribing designation marks to be used in association with such grades and providing for their proper use. The "National Mark" forms the main feature of all grade designation marks and it is a guarantee of the home origin and uniform grading and packing of any commodity to which it may be applied. Apples and pears came under the scheme on September 1st, 1928, and such of the season's crop as was sold under the "National Mark", was in most satisfactory demand.

The National Mark Egg Scheme, which was launched on February 1st, 1929, has met with an enthusiastic reception. Over 170 egg packing stations have successfully applied for permission to use the Mark. It is estimated that about 10 million eggs a week are being sent into the ordinary channels of trade under the Mark and demand is still in advance of supply. This must result in a greatly increased production in the near future. It is obvious that the success of any marketing scheme is largely dependent on the attitude of the distributing trades. It is, therefore, gratifying to note that the General Purposes Committee of the Federation of Grocers' Associations of the United Kingdom (representing 40,000 retail establishments) has resolved to give the scheme its whole-hearted support.

A National Mark Scheme for tomatoes and cucumbers was also put into operation this year, while schemes covering flour, poultry, beef, honey and other commodities are under consideration. A Scottish National Mark Egg scheme under the Department of Agriculture for Scotland will come into operation on June 1st, 1929, and a scheme for Scottish tomatoes is also ready.

One other aspect of this grant from the Empire Marketing Fund should be mentioned. Following a suggestion made in the Report on the Marketing of Pigs (Economic Series No. 12) and to some extent as a result of the interest aroused by the Pig Marketing Demonstrations, a Pig Industry Council has been set up and has begun active work.

Investigations into various aspects of marketing in Northern Ireland have been actively pursued with the aid of the grant (referred to in the last Report) to the Ministry of Agriculture, Northern Ireland.

Further details of the assistance being given by the Board to the home producer through the Ministry of Agriculture and Fisheries, the Department of Agriculture for Scotland and the Ministry of Agriculture, Northern Ireland, are contained in " The Empire Marketing Board and the Home Producer." [See Appendix IV.]

Wastage and Experimental Consignments.

The duty of examining and reporting upon fruit cargoes on arrival at London and Liverpool has continued to be performed by the Board's officers, as the value of such work has been emphasised by representatives of the oversea Governments concerned. Reports have been issued dealing with cargoes from Canada, Australia and New Zealand. An officer of the Board has again been seconded for service under the Government of Palestine and, in addition to supervising the recently established fruit inspection scheme, he has continued the series of experimental consignments based on pre-shipment records which were started last season. Several other experimental consignments of Empire produce have been received and reported upon.

United Kingdom Market Requirements and Retail Demand.

The Board has developed considerably during the past year its examination of these problems. Its work has been appreciated by the organisations which represent oversea producers in this country, and it has been greatly assisted by the goodwill shown towards its enquiries by the wholesale and retail trades. A national survey is being undertaken of the retail demand for butter, following upon more detailed studies in certain Midland towns. Other intensive studies in particular localities have been directed to cheese and to canned, dried and fresh fruits.

These investigations provide material of value not merely to those —often at a great distance—who are seeking to extend the market for their produce in the United Kingdom, but also to the Board itself in the direction of its publicity campaign. Information is being collected upon such points as the popularity of Empire produce with the retailer and the consumer, local preferences in such matters as varieties, grades and brands, the comparative advantages of different methods of packing and presentation, and the competition which different forms of Empire produce have to face.

III. OTHER SCHEMES.

Mechanical Transport.

Following the negotiations referred to in the last Report, a Directing Committee has been appointed by the Secretary of State to study every aspect of Mechanical Transport likely to further the economic development of the Oversea Empire. Sir James Currie, K.B.E., C.M.G., is Chairman and the other members are Sir Henry Fowler, K.B.E., Brigadier General F. D. Hammond, C.B.E., D.S.O., and Mr. Herbert Niblett, C.B.E., D.S.O. It is contemplated that the expenses of the Committee shall be shared between the Board, which will provide half the total amount, and the various oversea Governments who participate. In order to enable the work to begin without further delay, the Board undertook to meet in full the first year's expenses.

The Committee in the first place are aiming at developing transport units which, though not confined in their operations to good roads, will yet be able to handle larger loads than are now feasible. In particular, they are concentrating their attention on the production of a unit (of this nature) which will be able to handle a useful load of 15 to 20 tons, and are also working on the evolution of a larger unit to deal with loads of fifty tons or more. It is hoped that, by increasing the load now hauled in ordinary practice, the ton-mile cost of transport can be materially reduced. Experiments will be carried out in selected areas overseas as soon as the progress of the work justifies them.

The investigations are being conducted in close co-operation with the War Office, which has placed at the disposal of the Committee its experience in the manufacture and handling of heavy cross-country vehicles.

The Export of Pedigree Livestock.

The London Quarantine Station, established at the charges of the Empire Marketing Fund and managed by the Royal Agricultural Society, has fully justified the favourable expectations expressed in the last Report.

596 head of livestock have passed through the London Quarantine Station between its opening on April 4th, 1928, and May 31st, 1929. These were made up of 398 cattle, 128 sheep, 60 pigs and 10 goats and their destinations were, Australia, the Union of South Africa, the Mandated Territory of South-West Africa, Northern and Southern Rhodesia, Trinidad, and the Irish Free State.

The Quarantine Station, which contains 18 stalls and 26 boxes has been found adequate during the year for its purpose and there is a steady demand for accommodation in it. The Australian Commonwealth is the most recent of the Dominions to take advantage of the station, while Cyprus, which came in just before the close of the period under review, is the most recent of the Colonies.

The scheme for giving financial assistance under certain conditions towards the transport charges of pedigree stock exported to countries within the Empire is now in operation. Grants have already been made to the Governments of Southern Rhodesia, Kenya and Northern Rhodesia, and the Board are discussing with other Empire governments the extension of this scheme to their territories.

Special Mission to Australia.

The Economic Mission nominated by the British Government at the request of the Australian Commonwealth Government has published its Report and returned to this country. The Mission, the sea transport and certain incidental expenses of which were borne from the Empire Marketing Fund, visited every State in the Commonwealth and travelled some 20,000 miles within Australia. It saw areas of primary production and industrial centres and held over a hundred conferences with representative public bodies and associations of traders and producers.

The conclusions and recommendations of the Mission bear directly upon many matters of mutual economic interest to Great Britain and the Commonwealth and are receiving earnest attention in both countries.

Geophysical Surveying.

Mr. Broughton Edge, the Director of this expedition, landed in Australia in May, 1928, and field parties began work in June in New South Wales and Victoria. The preliminary investigations indicate that information is likely to be provided of value to mining engineers throughout the Empire and assistance given to the opening up of the mineral resources of Australia. The gravimetric, seismic and to some extent the magnetometric methods have been shown to be applicable to the " deep lead " areas of New South Wales, Victoria and possibly of Tasmania. The report of the expedition, when issued, will provide the first authoritative account of the limitations and possibilities of the methods employed.

IV. PUBLICITY.

" Ask first in your daily shopping for the produce of your own country. Ask next for the produce of the Empire overseas. Whenever you can find Empire produce, whether it be grown at home or overseas, that is satisfactory in price and quality, choose it in preference to foreign produce." This, briefly stated, is the policy by which the Board has throughout been guided in its publicity work. There has been no slackening in the period under review of this effort to bring out vividly and simply the general significance of Empire buying. The coming into force of the first Orders under the Merchandise Marks Act, and of the "National Mark", and the publication by the Imperial Economic Committee of Reports on Timber and Tobacco have added to the Board's duties in the sphere of publicity.

As in the past, the Board has not regarded large-scale campaigns in favour of specific commodities as coming within its normal scope. These have been left to individual advertisers whose appeals (to whatever Empire commodity they may refer) stand out in stronger relief against the background in favour of Empire buying continuously provided by the Board.

None of the channels of publicity previously followed has been abandoned. Experience gained in the earlier stages of the Board's existence has naturally afforded useful guidance. But state publicity in favour of an idea is largely a novel experiment and the Board is always conscious that it is learning. Reactions to its activity have, however, been encouraging and it is satisfied that its theme is being impressed upon a gradually widening circle of the public.

At the end of three years' existence, the Board feels justified in saying that never before has so much active interest been shown in this country in the practical questions of Empire marketing.

Newspaper Advertisement.

Two main series of advertisements, one completed and one still in progress, have been inserted in the general press in the period under review. The first dealt, one by one, with some of the great exporting industries of the United Kingdom and showed the importance to them of oversea Empire markets. Iron and steel, electrical engineering, cotton, ship-building, motor vehicles and bicycles and general engineering were reviewed from this angle and, in each case, the dependence of oversea Empire customers on the readiness of the United Kingdom to purchase their exports was forcibly emphasised. Special steps were taken to secure intensive publicity for these advertisements in the areas of the United Kingdom most directly affected.

The refrain running through this series was :—

> "What enables the Empire overseas to give orders for British manufactures ? The sale of Empire goods. How can you help the Empire and British industries ? By buying Empire goods."

The series aroused certainly as much interest as any others issued by the Board. The volume of favourable editorial comment in the newspapers, provoked by this handling of the Board's theme, was especially marked. Simultaneously with the insertion of advertisements in the press, an appeal based on the same arguments was given publicity through posters prepared by the Board and displayed in a large number of factories. Particulars of this scheme, which, is still actively being pursued, will be found on page 24 under the heading "Contract Posters."

A second series of advertisements, each dealing with a single commodity, but arranged, for purposes of cumulative effect, to present a unity, was begun in April and will continue for some months. Some twelve commodities from different parts of the Empire, the advertisement of which was felt likely to be especially advantageous, have been selected. Leaflets giving the story of the commodity and containing new and simple recipes have been prepared in connection with these advertisements and are being offered without charge to all applicants.

A number of other less general advertisements have been issued by the Board, as occasion required, including a special message to co-operators. Attention has been paid to keeping close liaison between the Board's press advertisement campaign and its other publicity activities.

Posters.

The Board has continued to show on its special frames sets of posters which are changed about once in three weeks; twenty sets have been shown in the period under review. Displays in many cities and towns, in which frames had already been erected, have been reinforced, while the number of cities and towns covered has been increased to over 300, bringing the number of frames up to 1,710.

The reproduction of suitable posters, for issue to schools, after they have been shown on the frames, has gone on. The number of schools in the United Kingdom which have applied to receive these reproductions has risen to no less than 23,000. A pamphlet telling the story of the poster has in each case been specially written and sent to the schools.

The Board has received substantial evidence from the general public, schools, traders, oversea Empire visitors and other quarters that its posters are helping to create an impression in favour of Empire produce.

Contract Posters.

A new departure in the Board's publicity was the preparation of a series of " Contract " posters for use in factories, where orders for the Empire overseas are being executed.

Sixteen of these have been prepared, each 20 in. by 30 in. in size and consisting of letterpress stating that " a contract is in hand in these works " for a given part of the oversea Empire and inviting the employees to help in securing further contracts by buying the produce of that part of the Empire. A reproduction of one of these posters is shown as the frontispiece to this Report. Miniatures have also been prepared for firms concerned to send to their customers overseas.

The scheme enjoys the invaluable co-operation of such representative bodies as the National Federation of Iron and Steel Manufacturers and the British Electrical and Allied Manufacturers' Association and has met with a most happy reception.

More than 10,000 posters have been supplied on application to over 500 firms covering all the principal exporting industries of the country and these totals show no sign of having reached a maximum.

Lectures.

The Board's lecture programme has progressed in 1928/9 on substantially the same lines as those approved for last year. The actual volume of work has remained materially unchanged, the total number of lectures delivered under the Board's auspices amounting to 2,438. The total audiences numbered approximately half a million.

It is evident from the reports which have been received that the Board's lectures are successfully achieving the object of creating and stimulating an interest in the products and resources of the Empire. One effect of the Board's activities has been to increase the proportions of Empire to other subjects in the normal lecture programmes.

The British Broadcasting Corporation have continued to broadcast in their series of talks to housewives fortnightly bulletins prepared by the Board. During the first three months of 1929, arrangements have also been made on an experimental basis for the broadcasting of selected recipes with notes on the Empire countries from which the necessary ingredients can be obtained.

Contact with the Trades.

Frequent discussions between members of the Board's staff and individual traders and regular attendance at meetings of retail trade associations, Chambers of Commerce and of Trade and similar bodies are avenues of approach which have been carefully explored. The volume of such work has grown very considerably in the past year. The retail trade has been particularly catered for by the issue of display material for use primarily in grocers' and fruiterers' shops. The policy of offering cups and prizes in connection with Empire Shopping Weeks has been continued.

Careful attention has been paid to linking up Exhibitions held in local centres with the stocking of Empire produce in the shops of the area concerned. A beginning was made on a large scale at Cardiff where a most successful Empire Exhibition was held from October 30th to November 10th, 1928. The Board circularised every wholesale firm known to be supplying Cardiff retailers with grocery or

provisions, giving in advance information of what would be shown at the Exhibition by the home country, the Dominions and Colonies, and pointing out that a favourable opportunity was thus offered for stimulating the wholesale distribution of Empire produce. Later, all retailers were similarly circularised and the attendants on the stands were supplied with lists of all retailers in the districts known to be stocking the produce being displayed. This method has since been applied at the Birmingham Grocers', Bakers' and Confectioners' Exhibition and at the North-East Coast Exhibition.

Enquiries about general questions of Empire produce and about specific commodities are being received in increasing numbers both from the trades and from members of the public.

The goodwill and keen co-operation of the grocery trade in this field have been invaluable to the work of the Board.

Exhibitions and Shopping Weeks.

The participation of the Board in the Jubilee of the Canadian National Exhibition at Toronto is the most prominent new feature of the year's work in exhibitions. The Board took this opportunity of showing the scope and nature of its activities to a uniquely large Dominion audience. Two million people passed through the Exhibition in the fortnight of its duration and the Board's pavilion was publicly and consistently described as the most striking exhibit.

As in the past the Board took a leading part in the main exhibitions and in many Empire shopping weeks in this country, providing space in its pavilion for the home country, the Dominions and such of the Colonies as desired to display their produce. At the Cardiff Exhibition mentioned above, 70,833 people visited the Board's Exhibition Hall and it is understood that this is a record for the attendance at any exhibition in Cardiff.

A new experiment is now being made at Newcastle, where the Board is represented at the North East Coast Exhibition by a pavilion in which during the six summer months the different Empire Governments will be represented by successive displays. The pavilion has won praise for its attractive qualities in high critical quarters. It was inspected in detail by the Prince of Wales in the tour which followed his opening of the Exhibition on May 14th. A feature of the pavilion is its exclusive use of Empire timber for both structural and decorative purposes.

A full list of the exhibitions in which the Board participated will be found in Appendix V. The Exhibitions Division of the Department of Overseas Trade again acted as the Board's agents.

Cinema.

The Board has continued the grant to the Imperial Institute for the maintenance of a Cinema in which Empire films are shown daily. During the year 1928, 214,830 persons visited this cinema, a large number of them being school children conducted in organised parties. An experimental extension of this work to the provinces has been associated with the North East Coast Exhibition, arrangements having been made with the goodwill of the local Education Authorities and the local branch of the Cinematograph Exhibitors' Association to give a display of Empire films to some 45,000 children in the Newcastle and Gateshead districts. A cinema is included in the Board's pavilion at the Exhibition, where films of Empire interest will be shown on the same lines as have proved successful at the Imperial Institute. During the winter a projector and selected Empire films were lent to the Leicestershire County Council, who utilized a travelling van in their possession for lectures and displays of films in a number of agricultural centres in the county. Favourable reports were received upon the way in which these displays were conducted and attended. Arrangements have also been made on a number of occasions to provide Empire films for special performances during Empire shopping weeks, or in schools.

A start has been made with the production of films specially adapted to the Board's purposes. Films based on the Herring Fishery and on the ingredients of the King's Plum Pudding are in course of preparation under the Board's supervision by leading British Companies. A short experimental talking film, designed to explore the possibilities of the education of the native producer by the cinema, is also being prepared with the ready co-operation of another firm.

Publications.

A number of additions have been made to the Board's publicity literature in the past year. Reprints were called for of the two pamphlets " What is the Empire Marketing Board ? " and " The Empire Marketing Board and the Home Producer," and of the " Calendar of Fruits and Vegetables " (of which 80,000 copies have been distributed). A further leaflet " Why should we Buy from the Empire ? " in which

the Board's theme is popularly set out, was published. " A Book of Empire Dinners " was issued, giving two menus for each month of the year, each prepared by a leading chef and including only Empire ingredients. By gracious consent of Their Majesties the King and Queen and Their Royal Highnesses the Prince of Wales and The Duke of York, three royal menus were included. The Lord Mayor of London kindly contributed a special menu to a collection that showed that there is no day in the year on which the Empire at home and overseas cannot supply a banquet of the first order with all its amenities. The first edition of 10,000 was exhausted in a few weeks and a reprint was demanded.

A " List of Empire Tobaccos," with brands named and prices given, of all available kinds of pipe tobacco, cigarettes and cigars and an attractively designed and decorated booklet of " Christmas Fare from the Empire " have been sent to all applicants.

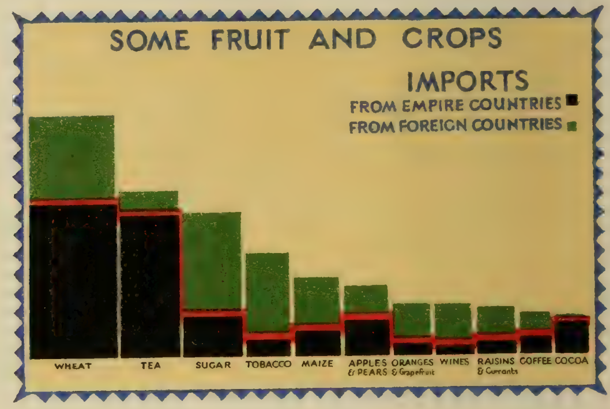
In connection with the " commodity " series of advertisements mentioned above, leaflets are being issued containing the story of each commodity and a few novel but simple recipes.

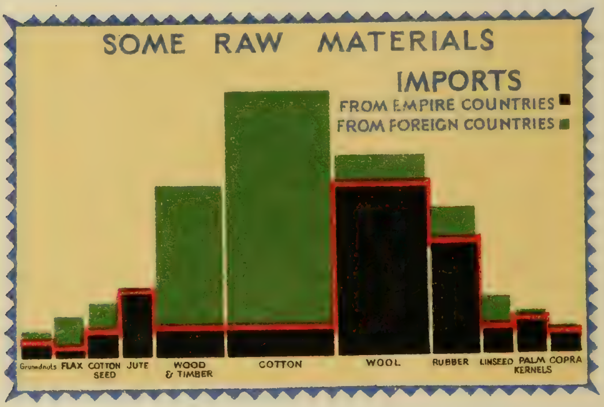
Other publications include the reprints of Empire recipes given out by the British Broadcasting Corporation.

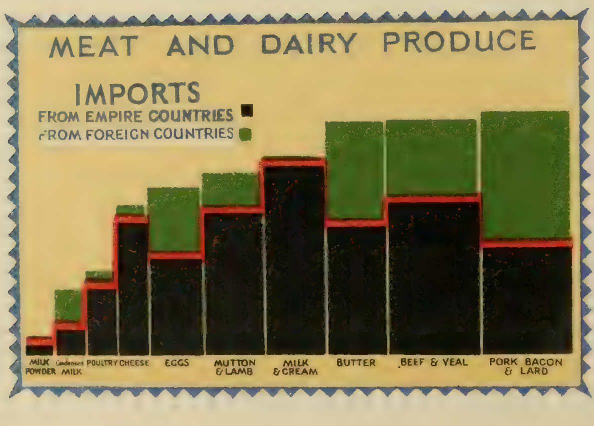
RECIPROCITY IN

SOME IMPORTS INTO THE UNITED KINGDOM

Over one third of the foodstuffs and raw materials imported into the United Kingdom comes from Empire Countries.







The United Kingdom takes over one third of the total exports from Empire Countries and one sixt[h] of the exports from Foreign Countrie[s]

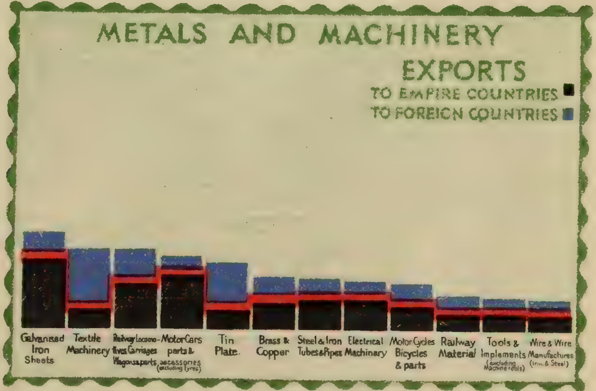
DIAGRAMS FROM POSTERS DISPLAYED THROUGHOUT THE UNITED KINGDOM

EMPIRE TRADE

SOME EXPORTS FROM THE UNITED KINGDOM

Almost one half of the manufactured goods exported from the United Kingdom goes to Empire Countries.

The United Kingdom furnishes over one third of the total imports into Empire Countries, but only about one ninth of the imports into Foreign Countries.



BY THE EMPIRE MARKETING BOARD
DURING 1928 AND 1929

APPENDIX I

(1) THE EMPIRE MARKETING BOARD.

The Secretary of State for Dominion Affairs and for the Colonies.
(The Rt. Hon. L. S. Amery, M.P.) (*Chairman*).
The Parliamentary Under-Secretary of State for the Colonies.
(The Rt. Hon. W. G. A. Ormsby-Gore, M.P.) (*Vice Chairman*).
The Financial Secretary to the Treasury.
(Mr. A. M. Samuel, M.P.)
The Parliamentary Secretary to the Ministry of Agriculture and Fisheries.
(The Rt. Hon. The Earl of Stradbroke, K.C.M.G., C.B.)
The Parliamentary Under-Secretary of State for Scotland
(Major Walter E. Elliot, M.C., M.P.)
The Rt. Hon. J. H. Thomas, M.P.
Sir Archibald Sinclair, Bart., C.M.G., M.P.
Sir Edward Crowe, C.M.G.
(Comptroller-General of the Department of Overseas Trade).
Sir Thomas Allen
Sir William Crawford, K.B.E. } (Great Britain).
Mr. W. A. Wilson (Canada).
Mr. F. L. McDougall, C.M.G. (Australia).
Mr. R. S. Forsyth (New Zealand).
Mr. J. Dimond (Union of South Africa).
Mr. J. W. Dulanty, C.B., C.B.E. (Irish Free State).
Mr. H. A. F. Lindsay, C.I.E., C.B.E. (India).
Sir Francis Newton, K.C.M.G., C.V.O. (Southern Rhodesia).
Sir Edward Davson, Bart. (Colonies and Protectorates).

Mr. S. G. Tallents, C.B., C.B.E. (*Secretary*).
Mr. E. M. H. Lloyd (*Assistant Secretary*).

(2) THE RESEARCH GRANTS COMMITTEE.

Major Walter E. Elliot, M.C., M.P., M.B., D.Sc.
(Parliamentary Under-Secretary of State for Scotland). (*Chairman*).
The Rt. Hon. The Earl of Stradbroke, K.C.M.G., C.B.
(Parliamentary Secretary to the Ministry of Agriculture and Fisheries).
The Rt. Hon. W. G. A. Ormsby-Gore, M.P.
(Parliamentary Under-Secretary of State for the Colonies).
The Rt. Hon. W. Graham, M.P.
Sir Edward Davson, Bart.
(Member of the Empire Marketing Board).
Mr. W. A. Wilson.
(Member of the Empire Marketing Board and the Imperial Economic Committee).
Mr. F. L. McDougall, C.M.G.
(Member of the Empire Marketing Board and the Imperial Economic Committee).
Mr. C. L. Stocks.
(H.M. Treasury).

Mr. E. M. H. Lloyd (*Secretary*).

(3) THE PUBLICITY COMMITTEE.

The Rt. Hon. W. G. A. Ormsby-Gore, M.P.
(Parliamentary Under-Secretary of State for the Colonies). (*Chairman*).

Sir William Crawford, K.B.E.
(Member of the Empire Marketing Board; Governing Director of Messrs. W. S. Crawford, Ltd.) (*Vice Chairman*).

Sir Thomas Allen.
(Member of the Empire Marketing Board and the Imperial Economic Committee).

Sir Woodman Burbidge, Bart., C.B.E.
(Chairman and Managing Director of Messrs. Harrods, Ltd.)

The Viscount Burnham, G.C.M.G., C.H.
(President of the Empire Press Union).

Sir Edward Crowe, C.M.G.
(Comptroller-General of the Department of Overseas Trade).

Mrs. Cottrell.
(Director of the Co-operative Wholesale Society, Ltd.)

Lieut.-Gen. Sir William Furse, K.C.B., D.S.O.
(Director of the Imperial Institute).

Mr. D. G. Gerahty (Director of Canadian Trade Publicity in the United Kingdom).

Mr. T. Johnston, M.P.

Mr. H. A. F. Lindsay, C.I.E., C.B.E.
(Member of the Empire Marketing Board and the Imperial Economic Committee).

Mr. F. L. McDougall, C.M.G.
(Member of the Empire Marketing Board and the Imperial Economic Committee).

Sir William Perring, J.P., M.P., (Representing the National Chamber of Trade).

Mr. F. Pick.
(Managing Director, Underground Railways, and London General Omnibus Co., Ltd.)

Lieut.-Col. N. G. Scorgie, C.B.E.
(Deputy Controller of H.M. Stationery Office).

Mr. J. C. Stobart.
(Director of Education of the British Broadcasting Corporation).

Mr. C. L. Stocks.
(H.M. Treasury).

Mr. G. Huxley, M.C. (*Secretary*).

(4) FRUITS COMMITTEE.

The Rt. Hon. J. H. Thomas, M.P. (*Chairman*) ; Mr. W. A. Wilson (E.M.B.) (*Vice Chairman*) ; Sir E. Davson, Bart. (E.M.B.) ; Mr. J. Dimond (E.M.B.) ; Mr. J. Forsyth Smith (Canadian Government Fruit Trade Commissioner) ; Mr. A. E. Gough (Overseas Farmers' Co-operative Federations, Ltd.) ; Mr. M. M. S. Gubbay, C.S.I., C.I.E. (Member of the Imperial Economic Committee) ; Mr. E. L. Jacobs (Institute of London Underwriters and the Liverpool Underwriters' Association) ; Mr. C. H. Lewis (representative of the National Federation of Fruit and Potato Trades Associations (Incorporated), Ltd.) ; Mr. E. M. H. Lloyd ; Mr. F. L. McDougall, C.M.G. (E.M.B.) ; Major E. G. Monro, T.D. (Member of the National Federation of Fruit and Potato Trades Associations (Incorporated) Ltd.) ; Mr. F. W. J. Moore (representative of the National Federation of Fruit and Potato Trades Associations (Incorporated) Ltd.) ; Mr. H. E. Stephens (New Zealand Fruit Board) ; Mr. H. V. Taylor, O.B.E. (Ministry of Agriculture and Fisheries) ; Dr. C. West (Cambridge Low Temperature Research Station, Department of Scientific and Industrial Research) ; Mr. J. W. White, O.B.E. (representative of the Fruit Brokers' Federation of Great Britain) ; Mr. N. L. Wright (Scientific Liaison Officer, New Zealand Government) ; Sir William Hardy, F.R.S. (Director of Food Investigation, Department of Scientific and Industrial Research) (Assessor). Mr. G. M. Dykes (*Secretary*).

(5) FILM COMMITTEE.

Major Walter Elliot, M.C., M.P. (*Chairman*) ; Mr. P. W. L. Ashley, C.B. (Board of Trade) ; Sir William Crawford, K.B.E. (E.M.B.); Lieut.-General Sir William Furse, K.C.B., D.S.O. (Director of the Imperial Institute) ; Mr. L. Hore-Belisha, M.P. ; Mr. H. A. F. Lindsay, C.I.E., C.B.E., (E.M.B.) ; The Hon. Mrs. Alfred Lyttleton, G.B.E., J.P. ; Mr. E. H. Marsh, C.B., C.M.G., C.V.O. ; Mr. F. L. McDougall, C.M.G. (E.M.B.) ; Mr. Harrison Watson (Chief Canadian Government Trade Commissioner in the United Kingdom) ; Mr. H. Vischer, C.B.E. (Colonial Office), Mr. C. L. Stocks (Treasury). Mr. J. Wilkie (*Secretary*).

(6) AGRICULTURAL ECONOMICS COMMITTEE.

Mr. F. L. McDougall, C.M.G. (*Chairman*) ; Sir David Chadwick, C.S.I., C.I.E. (Imperial Economic Committee) ; Mr. R. R. Enfield (Ministry of Agriculture) ; Mr. R. B. Forrester (London School of Economics, University of London) ; Sir Robert Greig, M.C., LL.D., F.R.S.E. (Secretary, Department of Agriculture for Scotland) ; Mr. J. B. Guild, M.B.E., (National Farmers' Union) ; Mr. H. A. F. Lindsay, C.I.E., C.B.E., (E.M.B.) ; Mr. E. M. H. Lloyd ; Mr. J. P. Maxton (Agricultural Economics Research Institute, Oxford) ; Mr. C. S. Orwin (Director Agricultural Economics Research Institute, Oxford) ; Mr. J. A. Venn (School of Agriculture, University of Cambridge) ; Mr. K. Walter (Secretary, Horace Plunkett Foundation). Mr. G. M. Dykes (*Secretary*).

(7) COLONIAL FRUIT GRANTS COMMITTEE.

Sir Edward Davson, Bart. (*Chairman*) ; Sir Gilbert Grindle, K.C.M.G., C.B. (Imperial Economic Committee and Colonial Office) ; Dr. A. W. Hill, C.M.G., F.R.S. (Director, Royal Botanic Gardens, Kew) ; Dr. E. J. Butler, C.I.E., F.R.S. (Director, Imperial Bureau of Mycology) ; Mr. H. Brown (Imperial Institute) ; Mr. F. A. Stockdale, C.B.E. (Colonial Office) ; Mr. E. M. H. Lloyd ; Mr. W. P. Hildred. Mr. R. F. Jenkins (*Secretary*).

(8) EDUCATION SUB-COMMITTEE (OF THE PUBLICITY COMMITTEE).

Lieut. General Sir William Furse, K.C.B., D.S.O. (*Chairman*); Mr. A. R. Ainsworth (Board of Education); Mr. H. A. F. Lindsay, C.I.E., C.B.E., (E.M.B.); Mr. J. W. Peck, C.B. (Scottish Education Department); Mr. J. C. Stobart (The Education Director, British Broadcasting Corporation). Mr. J. Wilkie (*Secretary*).

(9) RETAIL GROCERS' SUB-COMMITTEE (OF THE PUBLICITY COMMITTEE).

Mr. Lachlan Maclean, O.B.E. (*Chairman*); Mr. A. V. Alexander, M.P. (Parliamentary Committee of the Co-operative Congress); Mr. E. W. Andrews (President, Federation of Grocers' Associations of the United Kingdom; representing Bristol and District Grocers' and Provision Dealers' Association); Mr. C. L. T. Beeching, O.B.E., F.G.I. (Secretary, Institute of Certificated Grocers); Mr. John A. Calderwood (President, Belfast Grocers' Association); Mr. John Clarke, O.B.E., J.P. (Manchester, Salford and District Grocers' Association); Councillor A. E. Cobbin (Greater London Council of Grocers' Associations); Mr. G. W. S. Deadman (Display Manager, Army and Navy Co-operative Society); Bailie D. Fisher, J.P. (President, The Scottish Federation of Grocers' and Provision Merchants' Associations); Mr. A. J. Giles (Secretary, Federation of Grocers' Associations of the United Kingdom); Mr. P. Howling, F.I.S.A. (Secretary, National Chamber of Trade); Mr. Arthur A. Jones (Hull Retail Grocers' Association); Mr. A. Joyce (Kettering Industrial Co-operative Society); Mr. F. W. King (Liverpool and District Grocers' and Provision Dealers' Association); Mr. T. W. King, C.B.E. (General Manager, Civil Service Supply Association); Mr. A. G. Nichols (Cardiff and District Grocers', Tea Dealers' and Provision Merchants' Association). Mr. T. F. Skilton (*Secretary*).

(10) RETAIL FRUITERERS' SUB-COMMITTEE (OF PUBLICITY COMMITTEE).

Mr. Lachlan Maclean, O.B.E. (*Chairman*); Mr. R. G. A. Causer (Ministry of Agriculture and Fisheries); Mr. J. W. Clay (Bournemouth and District Fruiterers' and Florists' Association); Mr. L. Forrest (Manchester Association of Retail Fruiterers, Florists and Fishmongers); Mr. F. G. Hitchman (Birmingham and District Retail Fruit and Vegetable Dealers' Association); Mr. H. C. Knight (National Federation of Retail Fruiterers, Florists and Fishmongers); Mr. R. Loveridge (Bristol and District Retail Fruiterers', Greengrocers', Fishmongers' and Florists' Association); Mr. H. J. Mash (The Retail Fruiterers' and Florists' Association, Ltd.); Mr. T. D. Matkin (Secretary, The Retail Fruiterers' and Florists' Association, Ltd.); Mr. T. E. Metcalfe (Secretary, National Federation of Retail Fruiterers, Florists and Fishmongers); Major E. G. Monro, T. D. (Member of the National Federation of Fruit and Potato Trades Associations (Incorporated) Limited); Mr. E. D. Roberts (Liverpool Fruiterers' Association, Ltd.); Mr. R. Rush (Bradford and District Retail Fruiterers', Fish and Game Dealers' Association); Mr. Andrew Walker (Glasgow Fruiterers' and Florists' Association); Mr. James Waterworth (National Federation of Retail Fruiterers, Florists and Fishmongers). Mr. T. F. Skilton (*Secretary*).

(11) INFESTATION OF STORED PRODUCTS COMMITTEE.

Mr. E. M. H. Lloyd (*Chairman*); Mr. H. Brown (Imperial Institute); Dr. E. J. Butler, C.I.E., F.R.S. (Director, Imperial Bureau of Mycology); Dr. P. A. Buxton (London School of Hygiene and Tropical Medicine); Mr. J. C. F. Fryer (Ministry of Agriculture); Mr. F. Laing (National History Museum); Mr. T. W. Macara (Director of Research, British Association of Research for the Cocoa, Chocolate, Sugar Confectionery and Jam Trades); Dr. J. W. Munro (Assistant Professor, Department of Entomology, Imperial College of Science); Dr. J. G. Myers (Imperial Bureau of Entomology); Mr. H. C. Sampson, C.I.E. (Royal Botanic Gardens, Kew). Mr. W. S. Thomson (*Secretary*).

(12) DAIRY RESEARCH COMMITTEE.

Professor R. Stenhouse-Williams (Director, National Institute for Research in Dairying), Reading (*Chairman*)); Mr. E. B. Black (Institute of Agricultural Engineering, Oxford); Mr. J. F. Blackshaw, O.B.E. (Ministry of Agriculture and Fisheries); Mr. F. J. du Toit (South Africa); Professor R. H. Leitch (West of Scotland Agricultural College, and Board of Agriculture for Scotland); Mr. E. M. H. Lloyd; Mr. A. Poole-Wilson, M.B.E. (Irish Free State); Dr. A. J. M. Smith (Department of Scientific and Industrial Research, Cambridge Low Temperature Research Station); Mr. V. Stott (Department of Scientific and Industrial Research, National Physical Laboratory); Mr. F. Wigan (Australia); Mr. R. H. Wilkinson (Ministry of Agriculture, Northern Ireland); Mr. W. A. Wilson (E.M.B.); Dr. N. C. Wright (Hannah Dairy Research Institute, Scotland); Mr. W. Wright (New Zealand); Mr. A. More (Government Laboratory). Mr. R. F. Jenkins (*Secretary*).

(13) DAIRY INTELLIGENCE COMMITTEE.

Mr. E. M. H. Lloyd (*Chairman*); Mr. K. H. Bond, M.C. (Ministry of Agriculture and Fisheries); Mr. H. E. Davis (New Zealand Dairy Produce Board); Mr. F. Killick (Secretary, London Provision Exchange); Major J. R. King, D.S.O. (Australian Dairy Produce Board); Mr. E. R. Tidmarsh (Chairman, London Provision Exchange); Mr. W. A. Wilson (E.M.B.). Mr. J. A. Gilchrist (*Secretary*).

APPENDIX II

GRANTS OUTSTANDING FOR RESEARCH AND OTHER SCHEMES APPROVED BY THE SECRETARY OF STATE ON THE ADVICE OF THE EMPIRE MARKETING BOARD. (JULY, 1926, to MAY, 1929.)

Grants approved from June, 1928, to May, 1929, are shown in italics.

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
BIOLOGICAL AND AGRICULTURAL SCIENCES.			
Development of Biological and Agricultural Departments of the University of Cambridge.	*University of Cambridge.*	*10,000 for 5 years.*	*700,000 from International Education Board; 50,000 from Exchequer; 129,000 from other sources.*
TROPICAL AND SUB-TROPICAL RESEARCH.			
Development of a training centre for the study of tropical agricultural problems.	Imperial College of Tropical Agriculture, Trinidad.	21,000 capital; 8,000 maintenance in first year; *15,000 maintenance in second year; 16,000 maintenance in third year.*	21,000 from the Empire Cotton Growing Corporation.
Towards cost of maintenance of the Amani Institute, Tanganyika Territory.	Amani Institute, Tanganyika Territory.	6,000 p.a. for 3 years.	Contributions from East African Governments estimated at 12,000 p.a.

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Establishment in Northern Australia of a tropical research station.	Government of Commonwealth of Australia.	25,000 capital; 5,000 p.a. for 5 years.	25,000 capital; 5,000 p.a. rom Government of Commonwealth of Australia.
Towards the cost of the organisation and establishment of a Colonial Agricultural Service.	Colonial Office.	22,000 p.a. for 5 years.	Contributions from Colonial Governments, provisionally estimated by Lord Lovat's Committee at 110,000 p.a.
LOW TEMPERATURE RESEARCH.			
Development of the work of the Low Temperature Research Station, Cambridge.	Department of Scientific and Industrial Research.	35,000 capital; 8,000 p.a. for 5 years. *Supplementary capital grant of 3,500.*	—
Erection of new station at East Malling for cold storage experiments on a semi-commercial scale.	Department of Scientific and Industrial Research.	45 000 capital; 5,000 p.a. for 5 years. *Supplementary capital grant of 10,000. Maintenance grant of 5,000 for 1 year and 1,000 for 4 years.*	—

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Experimental investigations into the refrigerated transport of Irish Free State dairy produce.	Department of Scientific and Industrial Research.	1,000. *Supplementary grant of 700.*	—
ANIMAL HUSBANDRY.			
Research on the mineral content of natural pastures, with special reference to certain deficiencies in the soil and their effect on the growth and strength of livestock.	(*a*) Rowett Research Institute, Aberdeen.	2,000 p.a. for 5 years. *Supplementary grant of 5,000 for 3 years.*	—
Do.	(*b*) Commonwealth Council for Scientific and Industrial Research.	3,000 capital; 1,875 p.a. for 5 years.	3,000 capital; 1,875 p.a. for 5 years, half from Commonwealth Council of Scientific and Industrial Research, and half from the University of Adelaide.
Do.	(*c*) New Zealand Government.	2,000 p.a. for 2 years. *Further grant of 2,000 p.a. for 3 years.*	2,000 p.a. for 2 years provided in equal amounts by New Zealand Government and Cawthron Institute, New Zealand. *Supplementary grant of 2,000 p.a. for 3 years provided as above.*
Do.	(*d*) Government of Southern Rhodesia.	2,500 capital; 2,500 p.a. for 3 years.	2,500 capital; 2,500 p.a. for 3 years from Government of Southern Rhodesia.

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Training at Rowett Research Institute in technique of mineral contents research of Veterinary Officer appointed to the Falkland Islands.	*Government of the Falkland Islands.*	*100*	—
Stock-rearing Problems in Palestine.	Ad hoc Committee.	1,900. *3,000 spread over 3 years.*	1,900 from Zionist Organisation. *3,000 spread over 3 years from the Zionist Organisation.*
Erection of silo at School of Agriculture, Cambridge, for trials of the economic value of silage made from grass.	*School of Agriculture, Cambridge.*	*200*	—
Grants in aid of work at Cambridge University on the physiology and growth of farm animals, etc.	University of Cambridge.	5,000 capital; 400 p.a. for 5 years; 500 guarantee	11,000 capital.
ANIMAL BREEDING.			
Grant towards maintenance of Animal Breeding Research Department, University of Edinburgh.	University of Edinburgh.	10,000 capital.	60,000.
In aid of establishment at Animal Breeding Research Department, University of Edinburgh, of a museum for preservation of books, etc., of historical and scientific value to animal breeding.	*University of Edinburgh.*	*250*	—
ANIMAL HEALTH.			
Extension of the activities of the Onderstepoort Veterinary Research Station.	*Government of the Union of South Africa.*	*10,000 capital; 11,000 p.a. for 5 years.*	

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Research into Metazoan Immunity.	Liverpool School of Tropical Medicine.	3,000 p.a. for 3 years.	3,000 p.a. for 3 years from Liverpool School of Tropical Medicine.
Towards cost of Tse-tse Fly Research and Experimental reclamation in Tanganyika Territory.	*Government of Tanganyika Territory.*	*2,000 p.a. for 5 years.*	—
Investigation into use of B.C.G. vaccine in the protection of calves against tuberculosis.	*Department of Animal Pathology, University of Cambridge.*	*3,000.*	—
ENTOMOLOGICAL RESEARCH.			
Establishment of a laboratory for breeding beneficial parasites.	Imperial Bureau of Entomology.	15,000 capital; 5,000 p.a. for 5 years.	—
Investigation of the biological control of insect pests in the West Indies.	*Do.*	*2,000 for 3 years.*	—
Research into the entomological control of noxious weeds.	Cawthron Institute, New Zealand.	1,333 capital; 2,000 p.a. for 5 years.	667 capital provided by New Zealand Government, 200 by Cawthron Institute, New Zealand. 2,000 p.a. for 5 years provided by New Zealand Government and Cawthron Institute.

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Extension of accommodation for the Department of Entomology at the Natural History Museum.	Natural History Museum.	30,000 capital.	—
Investigations into the control of insects injurious to stored products.	Imperial College of Science and Technology.	250 capital; maintenance grant of 2,275 for 4 years. *Supplementary grants of 10,000 capital and 1,000 p.a. for 5 years for maintenance.*	—
Establishment of an organisation to pursue entomological investigations in Australia.	*Commonwealth Council for Scientific and Industrial Research.*	*25,000 capital; 2,000 special initial expenses in 1928. Maintenance grant of 9,300 in first year falling to 4,712 in fifth year.*	*25,000 capital; 2,000 in 1928 and maintenance grant of 9,300 in first year rising to 14,138 in fifth year from Government of Commonwealth of Australia.*
Research on problems of insect nutrition.	*Department of Entomology, London School of Hygiene and Tropical Medicine.*	*1,500 spread over 3 years.*	—
MYCOLOGICAL RESEARCH.			
Erection of a new building to house the Imperial Bureau of Mycology.	Imperial Bureau of Mycology.	8,000 capital.	4,000 capital from Imperial Bureau of Mycology.

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Investigation of the problem of dry rot disease of swedes and turnips.	Ministry of Agriculture and Fisheries.	520	—
Investigation of transportation rots of fruit exported from Palestine to the United Kingdom.	*Zionist Organisation.*	*450 p.a. for 3 years.*	—
FORESTRY RESEARCH.			
Towards cost of maintenance of Imperial Forestry Institute.	*Imperial Forestry Institute.*	*4,750 p.a. for 2 years.*	—
HORTICULTURAL RESEARCH.			
Extension of the work of the East Malling Horticultural Research Station with special reference to the standardisation of horticultural material.	East Malling Horticultural Research Station.	9,050 capital; maintenance grant for 5 years of 5,068 rising to 5,535 in fifth year.	—
Investigations into the keeping quality of fruit and its relation to the nutrition of the tree and soil conditions.	Long Ashton Horticultural Research Station.	7,025 capital; maintenance grant for 5 years of 2,425 rising to 2,750 in fifth year.	—
Investigations into the control of certain pests and diseases of particular interest to horticulturists.	Cheshunt Experimental and Research Station.	1,600 capital; 1,660 p.a. for 5 years.	—
ECONOMIC BOTANY.			
Visits of economic botanists to Dominions and Colonies and employment of botanical collectors for work overseas.	Royal Botanic Gardens, Kew.	4,000 p.a. for 5 years.	—

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Classification of herbarium specimens.	Royal Botanic Gardens, Kew.	2,000 p.a. for 2 years ; 819 p.a. for 3 years. *Supplementary grant for 4 years of 1,200 rising to 1,380 in fourth year.*	—
Towards cost of Expedition to Persia for purpose of collecting species of prunus.	*John Innes Horticultural Institution.*	*400*	*400 from the John Innes Horticultural Institution.*
PLANT BREEDING.			
Towards the establishment of a Plant Breeding and Seed Research Station at the New Zealand Agricultural College, Palmerston North.	New Zealand Department of Scientific and Industrial Research.	2,500 capital ; 2,500 p.a. for 5 years.	9,500 capital ; 5,670 p.a. for 5 years from New Zealand Government.
Prosecution and co-ordination of research in grasses and clovers.	Welsh Plant Breeding Research Station, Aberystwyth.	850 capital ; 950 p.a. for 5 years. *Supplementary capital grant of 3,500 and supplementary maintenance grant for 5 years of 3,550 rising to 3,900 in fifth year.*	—
Experiments on plants of the tidal zone with special reference to Spartina Townsendii.	*East Anglian Institute of Agriculture.*	*220.*	—

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Prosecution of research into the production of a variety of banana immune to panama disease and investigation into transport of bananas under cold storage conditions.	Imperial College of Tropical Agriculture, Trinidad, and Royal Botanic Gardens, Kew.	5,774 capital; 3,806 p.a. for 5 years.	—
PLANT PATHOLOGY.			
Investigation into virus disease in potatoes.	Scottish Society for Research in Plant Breeding.	4,450 capital; 1,430 p.a. for 5 years.	—
Investigation into virus disease in potatoes.	*University College, Dublin.*	*3,250 capital; 1,100 p.a. for 5 years.*	—
Extension of Research programmes on Virus Diseases of Plants at—			
(1) *Rothamsted Experimental Station, Harpenden.*	*Rothamsted Experimental Station, Harpenden.*	*1,835 capital; maintenance grant for 5 years of 2,345 rising to 2,965 in fifth year.*	—
(2) *Experimental and Research Station, Cheshunt.*	*Experimental and Research Station, Cheshunt.*	*1,040 capital; maintenance grant for 5 years of 1,080 rising to 1,260 in fifth year.*	—
Erection of " Wisconsin " tanks for use in research into cotton diseases.	Rothamsted Experimental Station, Harpenden.	600 capital; 200 for 1 year.	—

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
DIETETICS.			
Research work at the Lister Institute on the vitamin content of fruit, vegetables and dairy produce.	Medical Research Council.	4,000 p.a. for 5 years. *Supplementary grant of 1,000 p.a. for 4 years.*	—
Research into the physiological and pathological conditions associated with certain rationed and specialised diets, with special reference to Kenya native tribes.	Rowett Research Institute, Aberdeen.	3,000 p.a. for 2 years. *Further grant of 3,000 for 1 year.*	—
POULTRY RESEARCH.			
Scheme of poultry research on nutrition, marketing, etc.	Rowett Research Institute, Aberdeen, and Hillsborough Experimental Station, Northern Ireland.	7,000 capital; 2,500 p.a. for 5 years.	—
Study of quality in eggs and the effect of dietary factors on the hatching capacity of eggs.	Ontario Agricultural College, Guelph.	350 capital; 670 p.a. for 5 years.	350 capital; 670 p.a. for 5 years from Ontario Department of Agriculture.
Research on the Scientific Feeding of Poultry.	*Animal Nutrition Institute, University of Cambridge.*	*890 capital; maintenance grant for 5 years of 330 rising to 418 in fifth year.*	—

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Investigation of the production and marketing of table poultry, eggs, etc.	*Harper Adams Agricultural College.*	*5,000 capital; maintenance grant for 5 years of 1,581 rising to 1,816 in fifth year.*	—
DAIRY RESEARCH.			
Investigations into the problems of "red spot" in cheese and "fishiness" in dairy products.	National Institute for Research in Dairying, Reading.	1,600 p.a. for 2 years. *Supplementary grants of 3,150 for capital and 700 for 1 year for maintenance.*	—
Utilisation and marketing of dairy products, including feeding of milk to school children in Scotland, and enquiry into the utilisation of milk residues.	Department of Agriculture for Scotland; Scottish Department of Health, and the Ministry of Home Affairs, Northern Ireland.	7,760.	—
Survey of literature relating to the condensing and drying of milk and milk residues.	*Hannah Dairy Research Institute, Scotland.*	*500.*	—
Research on cheese ripening.	*University of British Columbia.*	*400 p.a. for 2 years.*	*400 p.a. for 2 years from the University of British Columbia.*
Production of Dairy Research Journal.	—	*1,000.*	—

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
FISHERIES RESEARCH.			
Research into the preservation and transport of fish.	Department of Scientific and Industrial Research.	20,300.	—
Investigation into the nature of the variations in the vitamin content of cod liver oils and the effect on the vitamin properties and marketing qualities of methods of manufacture and refinement.	—	3,000.	—
Towards the cost of the Great Barrier Reef Expedition.	Great Barrier Reef Committee.	2,500.	2,500 from Commonwealth Government of Australia, and 2,500 from scientific bodies in Great Britain.
WOOL RESEARCH.			
Research into fundamental problems of sheep breeding and determination of effective standards of raw wool.	Animal Breeding Research Department, University of Edinburgh, and the British Research Association for the Woollen and Worsted Industries.	10,000 capital; 3,000 p.a. for 5 years.	—
Survey of Empire Wools.	*British Research Association for the Woollen and Worsted Industries.*	*2,000 p.a. for 2 years.*	
Supply of Wool packs for trials in Australia, New Zealand and South Africa.	*Do.*	*175.*	

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
ZOOLOGICAL RESEARCH.		£	£
Research into fluctuations in the numbers of wild rodents.	*Department of Zoology, University of Oxford.*	*750 for 1 year and 850 p.a. for 2 years.*	—
AGRICULTURAL METEOROLOGY.			
Towards cost of Agricultural Section of Empire Meteorological Conference.	*Ministry of Agriculture and Fisheries.*	*500.*	—
OENOLOGICAL RESEARCH.			
Preliminary investigation into problems of maturation of wine.	*Ad hoc Committee.*	*1,250.*	—
GRANTS FOR COLONIAL DEVELOPMENT.			
Towards establishment of experimental fruit farm for testing the economic cost of growing and shipping bananas and grapefruit.	Government of Sierra Leone.	1,500 capital; 1,500 p.a. for 5 years.	1,500 capital; 1,500 p.a. for 5 years from Government of Sierra Leone.
Improvement of methods of cultivation, handling, drying and grading of copra.	Government of Fiji.	750 p.a. for 2 years.	—
Research into methods of drying copra of high quality for export.	*Government of the Federated Malay States.*	*1,150 p.a. for 4 years.*	*1,150 p.a. for 4 years from the Government of the Federated Malay States.*
Visit of nut expert to Nyasaland to examine the economic and horticultural aspects of nut cultivation.	*Government of Nyasaland.*	*200.*	*Contribution from the Government of Nyasaland.*
Engagement of specialist and assistants for citrus fruit cultivation in Palestine.	*Government of Palestine.*	*1,000 p.a. for 3 years.*	*1,000 p.a. for 3 years from the Government of Palestine.*

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Towards the salary of an Agricultural Officer appointed to British Honduras in connection with development of Citrus industry.	*Government of British Honduras.*	*280 p.a. for 3 years.*	*280 p.a. for 3 years from the Government of British Honduras.*
Sericultural Research.	*Government of Palestine.*	*100.*	*300 from the Government of Palestine.*
Development of Flax industry.	*Government of Cyprus.*	*2,500 spread over 3 years.*	*2,500 spread over 3 years from Government of Cyprus.*
MECHANICAL TRANSPORT.			
Experimentation and development of Mechanical Transport suitable for use in undeveloped parts of the Empire.	—	*20,000 in first year; 15,000 p.a. in second and third years; and 5,000 p.a. in fourth and fifth years.*	*Contributions from Oversea Governments of the Empire of 20,000 in second year, 15,000 p.a. in third and fourth years, and 10,000 in fifth year.*
GEOPHYSICAL SURVEY.			
A comparative trial of Geophysical methods of survey.	Imperial Geophysical Survey Committee.	16,000.	16,000 from Commonwealth Government of Australia.
ECONOMIC INVESTIGATION.			
Establishment of a Chair of Imperial Economic Relations at the London School of Economics.	*University of London.*	*2,000 p.a. for 5 years.*	—
Marketing of home agricultural products with special reference to the improvement of the existing methods of distribution and preparation for market.	Ministry of Agriculture and Fisheries.	40,000 p.a. for 5 years.	—

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Organisation of Egg Marketing in Scotland.	Department of Agriculture for Scotland.	1,000 p.a. for 5 years.	—
Marketing of Livestock and Agricultural Produce in Scotland.	*Department of Agriculture for Scotland.*	*2,500 for 1 year.*	—
Sundry marketing schemes in Scotland.	*Do.*	*1,000 for 1 year.*	—
Improvement of Pork and Bacon production in Scotland.	*Department of Agriculture for Scotland.*	*3,750 capital; 407 p.a. for 5 years.*	—
Investigation into the marketing of Northern Ireland Agricultural Produce.	Ministry of Agriculture, Northern Ireland.	900 p.a. for 3 years.	—
Investigation into the economics of small farms in Northern Ireland.	*Government of Northern Ireland.*	*600 p.a. for 3 years.*	*600 p.a. for 3 years from Government of Northern Ireland.*
Special mission to Australia to investigate various matters affecting the development of trade between Great Britain and the Commonwealth.	—	5,000. *Supplementary grant of 4,000.*	—
Collection and dissemination of data concerning the economics of agricultural production within the Empire, with special reference to the technique and results of cost accounting and survey methods.	Agricultural Economics Research Institute, Oxford.	700 p.a. for 5 years.	—

Object of Grant.	Department or Body to whom Grant made.	Expenditure involved in schemes approved by the Board.	Contributions by other bodies on which Grants from Empire Marketing Fund have been made conditional.
		£	£
Marketing of St. Vincent Arrowroot in the United Kingdom.	*St. Vincent Arrowroot Growers' Association.*	*250 p.a. for 2 years.*	*250 p.a. for 2 years from the St. Vincent Arrowroot Growers' Association.*
CO-OPERATIVE MARKETING.			
Fostering co-operative organisation of producers in the Empire and in aid of production of Year Book.	The Horace Plunkett Foundation.	1,500 p.a. for 5 years.	1,500 p.a. for 5 years from Horace Plunkett Foundation.
EXPORT OF PEDIGREE STOCK.			
Establishment of a quarantine station to assist the export of pedigree livestock to the oversea parts of the Empire.	Royal Agricultural Society of England.	7,750 capital; 3,250 p.a. for 5 years.	—
Towards cost of transport of pedigree livestock from the United Kingdom to Kenya.	Government of Kenya.	3,000 for first year; *1,500 for second year.*	3,000 for first year. *1,500 for second year from Government of Kenya.*
Towards cost of transport of pedigree livestock from the United Kingdom to Southern Rhodesia.	*Government of Southern Rhodesia.*	*2,280 for first year; 2,000 for second year.*	*2,280 for first year and 2,000 for second year from the Government of Southern Rhodesia.*
Towards cost of transport of pedigree livestock from the United Kingdom to Northern Rhodesia.	*Government of Northern Rhodesia.*	*600 for 1 year.*	*600 for 1 year from the Government of Northern Rhodesia.*

APPENDIX III.

EMPIRE MARKETING BOARD.—PARTICIPATION IN EXHIBITIONS DURING THE PERIOD MAY 1928—MAY 1929

Date.	Exhibition.	Remarks.
1928. 5–12 May	Olde Englysshe Fayre and Empire Exhibition, Alexandra Palace, London.	Full participation by Dominions and Colonies.
4–6 July	Aldershot Command and District Horse Show, Aldershot.	E.M.B. Information Bureau only.
10–14 July	Royal Agricultural Society's Show, Nottingham.	E.M.B. Information Bureau in connection with the Liquid Milk Publicity Campaign.
24 Aug.–8 Sept.	Canadian National Exhibition, Toronto.	Full participation by Dominions and Colonies.
10–12 Sept.	Display Convention Exhibition, Southampton.	Empire Window Dressing Competition.
10–14 Sept.	Manchester Tobacco Exhibition, Free Trade Hall, Manchester.	Full participation by Dominions and Colonies.
22–28 Sept.	International Grocers' Exhibition, Agricultural Hall, London.	Full participation by Dominions and Colonies.
2–4 Oct.	Kingston-on-Thames Empire Exhibition, Town Hall, Kingston-on-Thames.	E.M.B. Information Bureau only.
19–27 Oct.	Imperial Fruit Show, Belle Vue, Manchester.	Full participation by Dominions and Colonies.
30 Oct.–10 Nov.	Cardiff Empire Exhibition, Drill Hall, Dumfries Place, Cardiff.	Full participation by Dominions and Colonies.
23 Nov.–1 Dec.	Universal Cookery and Food Exhibition, Olympia, London.	Full participation by Dominions and Colonies.
27 Dec.–5 Jan. 1929	Schoolboys' Own Exhibition, New Horticultural Hall, London.	Special E.M.B. exhibit for schoolboys.

Date.	Exhibition.	Remarks.
1929. 15–24 Jan.	Birmingham Grocers', Bakers' and Confectioners' Exhibition, Bingley Hall, Birmingham.	Full participation by Dominions and Colonies.
6–16 Feb.	Woking Trades Exhibition, Woking, Surrey.	Composite Exhibit of Empire foodstuffs.
18 Feb.–1 Mar.	British Industries Fair, White City, London.	Full participation by Dominions and Colonies.
26 Feb.–23 Mar.	Ideal Home Exhibition, Olympia, London.	Full participation by Dominions and Colonies.
9–20 April	Belfast Grocers' Exhibition, Ulster Hall, Belfast.	E.M.B. Information Bureau only.
1–11 May	Scottish Grocers' Exhibition, Waverley Market, Edinburgh.	Full participation by Dominions and Colonies.
14 May–Oct.	North East Coast Exhibition, Newcastle-on-Tyne.	Full participation by Dominions and Colonies.

APPENDIX IV.

PUBLICATIONS OF THE EMPIRE MARKETING BOARD.

1. Single copies of the following publications may be obtained, free of cost, on application to The Secretary, Empire Marketing Board, 2, Queen Anne's Gate Buildings, London, S.W.1.

Leaflets :

The Empire Marketing Board : a brief description of the Board's work.
The Empire Marketing Board and the Home Producer.
Why should we buy from the Empire ?

Booklets :

A Calendar of the Fruits and Vegetables of Empire.
A Book of Empire Dinners.
A List of Empire Tobaccos.
Christmas Fare from the Empire.

Recipe Leaflets :

A series of leaflets of recipes showing places within the Empire which produce the ingredients required for each dish.

---

2. The following publications are obtainable from the sale offices of His Majesty's Stationery Office.

LONDON : Adastral House, Kingsway, W.C.2. MANCHESTER : York Street.
EDINBURGH : 120, George Street. CARDIFF : 1, St. Andrew's Crescent.
BELFAST : 15, Donegall Square West.
Or through any Bookseller.

E.M.B.1.	AGRICULTURAL ECONOMICS IN THE EMPIRE. Report of a Committee appointed by the Empire Marketing Board	6*d.*	(7*d.*)
E.M.B.2.	TROPICAL AGRICULTURAL RESEARCH IN THE EMPIRE with special reference to Cacao, Sugar Cane, Cotton and Palms. By C. A. Barber, Sc.D., C.I.E.	1*s.* 6*d.*	(1*s.* 8*d.*)
	REPORTS ON DEVELOPMENT OF AGRICULTURE IN CERTAIN COLONIES. By H. C. Sampson, C.I.E., Royal Botanic Gardens, Kew :—		
E.M.B.3.	Trinidad	3*d.*	(4*d.*)
E.M.B.4.	British Guiana	9*d.*	(10*d.*)
E.M.B.5.	Leeward and Windward Islands and Barbados ..	6*d.*	(7*d.*)

E.M.B.20

PANAMA DISEASE OF BANANAS.

REPORTS ON SCIENTIFIC VISITS TO THE BANANA GROWING COUNTRIES OF THE WEST INDIES, CENTRAL AND SOUTH AMERICA

By

CLAUDE W. WARDLAW, Ph.D., D.Sc., F.R.S.E.

Pathologist for Banana Research at the Imperial College of Tropical Agriculture, Trinidad,

and

LAURENCE P. McGUIRE, Ph.D., M.Sc., D.I.C.

Physiologist for Banana Research at the Imperial College of Tropical Agriculture, Trinidad.

JULY, 1929

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120 George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller.
1929.
Price 1*s.* 6*d.* Net.

70-221-20.

CONTENTS.

(36265) Wt. P2786/573/1929 1,500 7/29 Harrow G.3

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE.

Incorporated by Royal Charter.

Patron :
HIS MAJESTY THE KING.

The objects of the Imperial College of Tropical Agriculture, which was founded in 1921, are to provide training in the science and practice of tropical agriculture to students intending to become tropical planters, agricultural administrators or officers, or specialists in different branches of agricultural science and technology, and to offer facilities for the study of tropical agriculture to graduates of other colleges and universities.

An important feature of the College is the provision for research and investigation work which its laboratories and fields afford.

The College Buildings and Laboratories are situated in spacious grounds at St. Augustine, seven miles to the eastward of Port of Spain, Trinidad. Easy access to them is afforded by the Government Railway and the Eastern Main Road, both of which pass the College.

The College is controlled by a Governing Body of which the Chairman is Sir James Currie, K.B.E., C.M.G., and the Vice-Chairman Sir David Prain, C.M.G., C.I.E., LL.D., F.R.S.

The Principal is Mr. Geoffrey Evans, C.I.E., M.A., Dip. Agr., who is assisted by a staff of 9 Professors and 7 Lecturers.

By arrangement with the Empire Marketing Board and with the co-operation of the Royal Botanic Gardens, Kew, and the Low Temperature Research Stations at Cambridge, long range research in connection with bananas is being conducted by the Imperial College at St. Augustine.

Particulars regarding the College and its work can be obtained from the Secretary, Sir Algernon Aspinall, C.M.G., C.B.E., 14, Trinity Square, London, E.C.3.

PREFACE.

In 1903 a destructive plague appeared among the promising banana plantations of Panama ; and large areas, both in that country and in Costa Rica were soon abandoned by their cultivators. This disease, known as Panama Disease, has spread to other Caribbean lands and is a persistent menace to the banana crop there.

The rapid spread of Panama Disease and the heavy losses resulting from it formed one of the problems which had to be considered by the Imperial Economic Committee when their Report on Fruit was being prepared in 1926. The staff of the Royal Botanic Gardens, Kew, were already at work on the search for a variety of banana which, while retaining the economic advantages of the Gros Michel usually grown in the British West Indies, should be immune to the dreaded Panama Disease. The Imperial Economic Committee recommended that these researches should be pushed forward, and that financial assistance should be given to that end.

Acting on this recommendation the Empire Marketing Board has made grants to the Imperial College of Tropical Agriculture, Trinidad, and to the Royal Botanic Gardens, Kew, for research into the production of a banana plant immune to Panama Disease and for investigation into the transport of bananas under cold storage conditions.

An investigator from Kew has been at work in the East, the original home of the banana, searching for varieties which might develop the desired qualities ; and some promising finds have been made. It is necessary, however, to proceed with the utmost caution. These promising varieties cannot be introduced into the West Indies without a period of quarantine, for fear of introducing diseases common to bananas in oriental countries more serious than Panama Disease itself. The specimens are, therefore, brought to a quarantine house at Kew for testing and propagation, pending their despatch to the West Indies.

Meanwhile the Imperial College of Tropical Agriculture is studying the disease itself and the best means of combating it. It has for some time been thought that the multiplication and spread of *Fusarium cubense*, the organism responsible for Panama Disease, is closely connected with lack of fertility and with adverse soil conditions. Dr. Claude W. Wardlaw, the Pathologist for Banana Research

attached to the Imperial College of Tropical Agriculture, has made a tour of the banana producing countries in the Caribbean area, and has investigated the conditions which have led to the abandonment of plantations. In particular, he has examined the conditions in which Panama Disease has been prevalent. His Report gives an account of his observations in that field, and indicates the conclusions suggested by the survey.

The Report by Dr. Laurence P. McGuire, Physiologist for Banana Research at the Imperial College, emphasises in a striking way the conclusions arrived at by Dr. Wardlaw as a result of his tour. The cause of abandonment of banana lands in the areas visited is not, it is stated, solely due to the ravages of Panama Disease. Other factors such as unsuitable soils, high cost of management, water logging, and the like also contribute. On the other hand Dr. McGuire confirms the observations previously arrived at by officers of the Imperial College in the course of their experiments to the effect that certain varieties possess considerable powers of resistance to Panama Disease.

WALTER ELLIOT,

Chairman of the Research Grants Committee.

Empire Marketing Board,

May, 1929.

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE,
TRINIDAD.

24th November, 1928.

To The Empire Marketing Board.

Gentlemen,

This report gives an account of my visits to Barbados, St. Lucia, Costa Rica, Guatemala, British Honduras, Jamaica, Colombia, and Panama. The information conveyed here is necessarily selective, and only data germane to the subjects of banana cultivation, disease, or abandonment have been submitted. Where information can already be obtained in published form, as in the case of Jamaica, the report is brief, but where accurate accounts have not hitherto been available, the observations are set out in greater detail. I shall be glad to discuss other aspects of the subject if desired.

Panama Disease is an investigation of great complexity, not only on mycological grounds, but also because it is closely interwoven with the many unexplored problems relating to the deterioration of virgin soils. Thus my visits to Central America have shown clearly that Panama Disease is not necessarily the only, or in all cases, the principal factor for large scale abandonment. Other factors such as choice of land, inadequate soil exploration, drainage, supply of planting material, etc., are also important, but in the primitive state of agriculture in a new country, the tendency is to assign all failures to any important contemporary disease. Thus in the absence of a personal visit, one would be greatly misled by the information in current circulation.

These several visits have served to indicate that the problem is of great scientific interest, and that its solution will call for detailed pathological and physiological studies, together with careful observations on the behaviour of virgin soils under intensive and continuous single crop exploitation.

I have the honour to be, Gentlemen,

Yours respectfully,

CLAUDE W. WARDLAW.

PANAMA DISEASE OF BANANAS.

REPORT TO THE EMPIRE MARKETING BOARD ON A SCIENTIFIC VISIT TO THE BANANA GROWING COUNTRIES OF THE WEST INDIES, CENTRAL AND SOUTH AMERICA.

By Claude W. Wardlaw, Ph.D., D.Sc., F.R.S.E.

INTRODUCTION.

PANAMA Disease of Bananas has already received considerable attention at the hands of scientists and at the present time published accounts concerning it have emanated from practically every banana growing country in the world. So widespread is the disease that it is unnecessary to enumerate these several countries at this point. So far as the investigations have gone the reports as to the nature of the disease are in substantial agreement, with some minor differences in detail.

It is now generally recognised that Panama Disease is a pathological problem of great complexity, occurring under a considerable variety of conditions. The several banana growing countries, however, are so vast and so varied in geology, topography, river action, soils, climate, etc., that investigations tend to suffer from the defect of localisation. Further, general scientific information regarding some of the larger countries is so scanty at the present time that a personal visit must be made in order that the special conditions prevailing there may be justly apprehended. Thus the ignorance and mis-statements which obtain with regard to the banana and Panama Disease may be taken as an indication of the broad scientific field which yet remains to be explored.

Under the Banana Research Scheme at the Imperial College of Tropical Agriculture, Trinidad, B.W.I., travelling facilities have been provided, and it has been possible to make scientific visits to a number of the more important banana growing countries. The present report will be concerned with an account of the author's travels in the West Indies and in Central and South America.

While many investigators have tackled the problem of Panama Disease even at the present time the work lacks completeness, and in fact has advanced little beyond the initial mycological stage. When it is stated that the disease is a wilt disease of great severity caused by the parasitic soil organism *Fusarium cubense* on the suckers and

roots, little has been omitted in assessing the extent of our present knowledge. The early investigators and their followers were so struck by the severity of the disease that they at once proceeded to launch an appeal for an immune banana to replace the Gros Michel in the trade and to apply drastic quarantine measures. Throughout the course of the several researches great stress has always been laid on the mycological evidence, and very little attention appears to have been given to exploring possible accessory conditions. This is readily understood, because the disease may apparently occur under such a variety of conditions that the investigator is led to conclude, hastily or otherwise, that the organism is such a powerful parasite that it will attack under all conditions—a statement not entirely justified when the manner in which the disease progresses is considered. All the evidence points to the fact that the mycological evidence must be read in conjunction with a sound knowledge of field and growth conditions and of the general physiology of the banana. It has already been suggested that banana information in current circulation suffers from the defects of incompleteness and localisation. Thus, for example, it is generally thought that the great abandonments of banana land in Central America were entirely due to the ravages of Panama Disease, and that all the land originally planted was of exceptionally high fertility. But such statements do not convey the whole truth. There were many reasons for abandonment, while even a little experience indicates that banana lands are very varied in type, fertility and staying power, to say nothing of important climatic differences. But information on these matters cannot be culled from rumour. The solution to the problem can only be justly sought by personal contact with the several local conditions. Regarding the nature of Panama Disease the pathologist on his travels has in mind two contrasting points of view. One is that the disease may be purely a matter of susceptibility as determined by the genetic constitution of the plant. The other is that the disease may be due to external conditions, soil, and climate, which adversely affect the health of the plant leaving it a prey to the parasitism of *Fusarium cubense.* It will be shown that as a rule, in our present state of knowledge, there is something to be said on both sides.

This report, based on seven months of travel in several of the important banana growing countries, gives the author's general impressions of banana disease problems, and is the basis for the experimental work whick has now been commenced at the Imperial College of Tropical Agriculture, Trinidad, B.W.I. To the staff of the

College and to the facilities for work provided there, the writer is already deeply indebted. From the outset, Mr. G. Evans, M.A., C.I.E., Principal, has shown great interest in the research and has kindly assisted with all travel programmes. In thanking him the writer wishes also to associate Professor H. R. Briton-Jones, and Professor E. E. Cheesman. The former has already had experience with the problem of Panama Disease and has assisted by generous discussion at all times. To the latter, who has already made considerable progress with the uniquely difficult problems of banana cytology and genetics, the writer is indebted for much sound information regarding varieties and for constant assistance in the field. Such co-operation from members of the staff, and access to the collection of banana varieties on the College grounds available for study and experiment, are regarded by the writer as important factors in pursuing successfully any investigation into the physiology or pathology of the banana.

BARBADOS.

At the present time the Windward Islands, together with Barbados and Trinidad, cannot be regarded as banana producing colonies, although all have bananas in cultivation for local use, and at one time or another have had a small export trade. Thus a banana industry was started in Barbados in 1902, the first shipment consisting of 18 bunches of the Canary banana (*Musa Cavendishii*), the second in 1903, of 6,669 bunches, jumping to 15,000 bunches in 1904, and 21,000 bunches in 1905. This small but prosperous business, however, did not continue, and Fawcett tells how a similar banana industry in Trinidad monopolised all the space available in the cold storage holds so that the Barbados fruit, of necessity stored in the ordinary holds, arrived at its destination in a rotted condition. The losses sustained under the attendant circumstances were so severe that shipments were discontinued and the banana land was planted up in sugar cane. An attempt was made in 1913 to restore the banana industry, but at the present time there is no export of bananas from Barbados ; in point of fact the reverse is the case and at certain seasons small quantities of bananas are imported from the neighbouring islands. If one might point a moral it would be that co-operation and not competition among these islands is the only key to success.

Apart from certain areas where the Dwarf Banana may be grown, Barbados is not a banana country. The soil is too porous, the rainfall

is low, and the island is constantly swept by winds. There are no banana estates to be visited in Barbados at the present time. I visited two small holdings where disease was reported, but these proved to be physiological troubles due to insufficient attention and the need for soil improvement. All the bananas with the exception of those growing in favourably sheltered habitats appear to suffer from drought in the dry season, the leaves being wilted and folded, papery, and whipped to tatters. Chlorotic plants were observed growing in the screes of calcareous cliffs. In the North East district where the soils are very friable and of a red and brown colour, one can still see the remains of the old banana walks. No Panama Disease has been reported from Barbados.

ST. LUCIA.

During my visit to St. Lucia in June (1928) I was able, with the co-operation of Mr. E. A. Walters, Superintendent of Agriculture, to examine all aspects of the Banana industry there. This visit was especially interesting because it indicated clearly the great need for scientific knowledge before launching any new agricultural project. Like Trinidad and Barbados, St. Lucia has now no important banana industry, but as recently as 1922 there was a somewhat ill-conceived venture in that direction. As the whole history of this attempt to establish a banana trade is known, I suggested to Mr. Walters that he should write an account of it from the commercial and scientific point of view. This is now available in the form of articles submitted to *Tropical Agriculture.** From the standpoint of an investigator the points are as follows. Towards the end of 1922 a banana company took over an area of Crown Land Forest in the Ravine Poisson, cleared the land sufficiently to allow of planting, and felled the virgin forest, more or less following the method commonly used in Central America. The land was chosen and the operations commenced without seeking the advice or assistance of the local agricultural authorities. The first plantings, to establish a nursery, were made from suckers of the Gros Michel collected promiscuously throughout the island, and there can be little doubt that much defective and diseased material was introduced into the nurseries at the very outset. The first cases of Panama Disease were observed towards the beginning of 1924. By this time the Agricultural Authorities had been called in to give advice on Weevil and Borer

---

* *See* Appendix.

pests and other difficulties, and certain preventative measures based on the Jamaican regulations were applied. Planting went on, Panama Disease was observed in several new localities, new troubles arose and the Agricultural Department did good work in several directions, notably in the selection and preparation of planting material, whereby a considerable reduction in the amount of disease was effected. From an original area of 200 acres in the Ravine Poisson cultivation was extended to 1,000 acres, so as to include the Vanard Estate. But the industry was not destined to be successful. Overhead costs were heavy, porterage was difficult and expensive, and after four

Fig. 1.—Banana land in St. Lucia, showing the steep exposed hillsides, into wind-breaks of the original forest trees. In the foreground is a typical abandoned area in which the remaining bananas are gradually being crowded out by secondary vegetation.

shipments the industry collapsed, not on account of Panama Disease, but on financial grounds. By 1925 the whole attempt had completely failed and the banana lands were allowed to go back into secondary bush. My investigations in the Ravine Poisson and Vanard were, therefore, made on derelict land covered with secondary bush. While these banana lands are not of the first class judged by Central American standards it is important to note that Panama Disease,

though it had caused great havoc in the first 200 acres planted, was not the cause of failure. At the time of abandonment there were still big areas growing good fruit, with localised bad patches of Panama Disease. From the scientific aspect these areas present many points of interest. Judged by the Central American concept of banana land for large scale production, the soils of St. Lucia are unsuitable. The plantations were situated on steep hillsides, road-making was very expensive as it necessitated deep cuttings and bringing out the fruit undamaged was difficult. Further the soil is not of the first order in its natural state being for the most part a rather sticky

Fig. 2.—An example of the deep cutting required to secure a roadway into the Ravine Poisson, St. Lucia. This type of excavation extends from the bottom to the top of the ravine.

loamy clay of red or yellow colour, with defective aeration and drainage. Such soil puddles readily, has all the defects of impervious clay, and is not readily modified by the decaying surface mould. In short this type of soil requires to be worked before planting, if a good staying fertility is to be obtained. Near the top of the ridges where one finds the stiff clays which have resisted denudation plants show drought symptoms in dry weather, while in the hollows below

Fig. 3.—A general view of an abandoned hillside area, showing Gros Michel bananas in competition with the secondary vegetation.

where detritus has collected a more uniform undisturbed growth is the rule. The Gros Michel banana does not take kindly to soil of this kind, and in many instances I found the plants growing like soil epiphytes rooted in the accumulation of their own mould. Where the roots had penetrated into the clay they were obviously water-soaked and diseased. In such habitats there is clearly an important problem of root decay in addition to that caused by the Panama Disease organism. Land of this type, though of high potential fertility will not give good results unless it receives suitable agricultural treatment. In Central America where there is no cultivation (in the sense of thorough tillage) the good banana lands consist of deep alluvium, and on such soil, with the help of rough bushing, the Gros Michel is able to thrive. Again, in Jamaica, land corresponding to that of St. Lucia has supported bananas for many years, but there tillage is the rule. In St. Lucia, on the other hand, no tillage (other than digging a small hole to plant the sucker or " bit ") was given and there is little doubt that such treatment would not be conducive to long-lived highly productive plantations on these difficult hillside soils. There is an idea prevailing in many quarters that all virgin land is necessarily of unbounded fertility, but a little experience shows that the term " virgin soil " may include a wide range from a rich deep alluvium to surface material which is more in the nature of a juvenile geological stratum than soil. Thus in the question of tropical soils we have a hundred unexplored problems. The experience in St. Lucia clearly indicates that under the conditions described above the soil quickly undergoes a marked deterioration when planted in bananas. The secondary bush which encroached on the abandoned areas was of a poor type and the dominance of certain ferns may be taken as an indication of the biological conditions. In order to conserve the natural wealth of such land, therefore, some kind of detailed agricultural treatment is essential.

With regard to the economic value of the original banana lands, Walters offers the suggestion that the best areas would serve admirably for coffee. Such suggestions are welcome because one of the major difficulties under such conditions is to find a suitable alternative crop. Numerous examples of Panama Disease were observed, but in the area where such plants occurred there were still many healthy plants carrying fair bunches of fruit. Good plants were frequently observed in close proximity to diseased ones, and in view of the fact that the organism has had at least two years to spread from infected stools

to the neighbouring ones it makes one doubt some of the current theories and statements concerning the nature of the parasitism. Considering that the organism can grow through the soil, coupled with its alleged virulence under all conditions, theoretically there should be practically no bananas left standing. But this was not so. In St. Lucia the question of Panama Disease is rendered more complex by the growth of the Gros Michel under conditions not entirely suitable. To what extent these two aspects are related remains to be demonstrated by critical experiment.

Note.—According to Walters, the frequency of Panama Disease was as follows :—S.W. area of the colony, 0·7 per cent. ; N.E. area, 2·5 per cent. ; lands of Banana Company from 0·5 per cent. to 20 per cent.

COSTA RICA.

Commercial banana production began in Costa Rica about 1880, when only 360 bunches of bananas were exported, but after the railway was opened production increased rapidly till it reached about 10 million bunches annually from 1908–11 :—

1882	3,500
1892	1,178,812
1902	4,174,199
1908	10,060,009
1909	9,365,690
1910	9,097,285
1911	9,309,586

Since then the abandonment of land for banana cultivation has led to a decrease in output, so that Costa Rica took fourth place in the export of bananas in the Caribbean with a total of 7,660,000 bunches in 1926.

The interior of Costa Rica is highly mountainous, the lofty volcanic ranges following the general trend of the continent from N.W. to S.E. On the Atlantic and Pacific sides of this broken central table-land are narrow coastal plains some 30 miles in width. Denudation in the upland regions is rapid, and swift rivers, constantly carrying sediment, flow down to the plains and deposit rich beds of alluvium. The river courses along the plain are flat and meandering, with the result that these alluvial lands are constantly in the process of formation.

The climate on the Atlantic side is very humid. The high rainfall is distributed over the whole year, with a rather drier period from January to April. As a result of the high precipitation and rich

alluvial soil, the Caribbean coastal plain and hillsides are covered with dense tropical rain forest—giant trees, with a heavy undergrowth of lianes, and Palm jungles. It is this land which has been pressed into the service of large scale banana production.

The writer had the opportunity (by courtesy of the United Fruit Company) of visiting the banana lands of Costa Rica on two occasions, in July and September, and was able to see most aspects of the industry in its present state. Banana cultivation in Central America by no means infers detailed agricultural operations such as tillage,

Fig. 4.—An alluvial area in Costa Rica, covered in virgin rain-forest vegetation. This indicates the nature of the country that has been opened up for large scale banana cultivation.

liming, upkeep of plant food, etc. It would be more accurately described as the exploitation of the native fertility of virgin soil with the minimum amount of detailed treatment. The method of establishing a plantation is briefly as follows. An area is surveyed and the underbush of the virgin forest is cutlassed sufficiently to allow the laying out of the rows, the position of each stool being marked by a stake: suckers or "bits" are then planted in holes 15 inches in diameter and 15 inches deep. The tall forest trees are then felled

and after some time the young banana plants begin to appear through the mass of trunks, branches and twigs. As both the growth of the plant and the decay of the forest debris take place quickly, in a very short time, with periodic cutlassing of the secondary bush, an orderly plantation is established.

During my first visit in July I was able to see examples of the best and of the worst plantations, and this afforded a valuable sense of contrast. For the most part the plantations are situated in flat country along rivers, lagoons, and railways, on rich alluvial soils deposited by

Fig. 5.—Felled forest land in Costa Rica being opened up for banana cultivation.

the meandering rivers. In some districts the latter may overflow two or three times a year. Monte Verde, the first farm visited, is situated some 30 miles out of Port Limon, on the main line to San José ; it consists of an extensive area of flat country originally clothed in tall forests of giant trees. I was informed that the farm extends over 2,000 acres, has about 900 labourers, a tram-line system, loading sidings, many mules, and hundreds of pontoon bridges. This piece of country is very flat, lying perhaps 100–150 feet above sea level. Drainage is into an adjacent river whose course is marked by many

Fig. 6.—Felling operations in a Costa Rican forest in preparation for banana cultivation.

Fig. 7.—A banana plantation at an early stage. The young plants are pushing up through a tangled mass of trunks, branches, and twigs. Costa Rica.

Fig. 8.—Appearance of new plantation in the apparently disorderly early stage. The land is covered with forest debris from giant trees (*see* right hand side) through which the young plants, set out in rows, are pushing up.

Fig. 9.—A Costa Rican alluvial plain, originally covered in dense forest, transformed into productive banana plantations. This illustration gives some idea of the extensiveness of some of the valleys under bananas.

loops, some of which are eventually shut off as lagoons. Although the land is superficially uniform—the result of successive depositions of river alluvium—yet marked differences occur in the soil, the natural flora, and the banana plantations from area to area. When such land is opened up for banana cultivation this soil variability is reflected in the growth and longevity of the banana plantations. My first visit was to a very good plantation, which had been producing consistently for 20 years. It was a remarkable sight. The plantation as a whole was marked by great uniformity of growth, by tall robust plants of high productivity, by the miniature undergrowth which scarcely required cutlassing, and by the absence of Panama Disease. Examination of the soil showed it to be a free, well-drained, moisture-holding dark sandy loam. In other words, in its natural state it was practically an ideal banana soil. I had a section dug through a stool to a depth of four feet. The excellent soil observed on the surface continued downwards with a slight increase in the quantity of finer particles, and it was noticeable that the majority of the roots penetrated vertically downwards, rather than horizontally; they were free from disease, white and turgid, with a plentiful growth of unblemished lateral rootlets.

The presence of easily observed root-hairs may be taken as an indication of the soil texture. Uprooting by wind was at its minimum in this plantation. Lastly, it should be mentioned that there was an even transition (from the surface vegetable mould from a species of *Tradescantia*) down into the lower depths of the soil. These several points, together with a knowledge of the age of the plantation may all be taken as indications of exceptional fertility and suitability to the Gros Michel. In fact, it gave one a definite concept of a high class Gros Michel soil which proved very useful in subsequent comparisons. All the soils of this area, however, were not of the same high order. A second soil examined did not support the same strong even growth; it was of lighter colour, was less sandy and open in texture, and tended rather to stiffness and compactness. Other similar soils were examined. These were silty loams of brownish colour, so compact as to make root penetration difficult, and somewhat mottled and streaky, indicating deficient local drainage and lack of aeration. Alluvial soils of this kind would doubtless respond to even a little treatment, while mechanical stirring, if only to a minor extent would greatly improve root formation and health by allowing greater freedom and aeration. But this they do not receive in the present

state of agricultural development, and the banana plant has perforce to grow as well as it can from the 15-inch excavation in which it is planted. The contrast between these latter soils and the first one described was very marked indeed. Other areas of poorer soil showed smaller banana plants, uneven growth in the plantation as a whole, gaps here and there, and a greater amount of Panama Disease. Where the growth of the banana is poor and uneven the secondary bush naturally is much more active in growth, and requires to be cutlassed more frequently. Thus, quite apart from the ravages of Panama

Fig. 10.—The River Reventazon, Costa Rica. This is a typical banana river. It brings down rich silt from the hills, and deposits it as it meanders across the plain. This photograph illustrates the nature of land resulting from a succession of silt depositions. The river banks are built up as the result of a succession of floods.

Disease certain plantations fail to give the necessary margin of profit because poor production of fruit goes hand-in-hand with higher cost of upkeep. Very good soils, or soil replenished every year by the deposition of good alluvium from the rivers, appear to be rich enough to stand continuous cultivation. Other soils of the second or third class of fertility may last from 7 to 10 years. In the deterioration of tropical soils which takes place under these methods of exploitation

we have a problem of first-rate importance. Its solution is to be sought in the conservation of fertility by detailed agricultural treatment or by a suitable rotation of some kind.

With regard to the occurrence of Panama Disease it was observed practically everywhere, but it was most accentuated where growth as

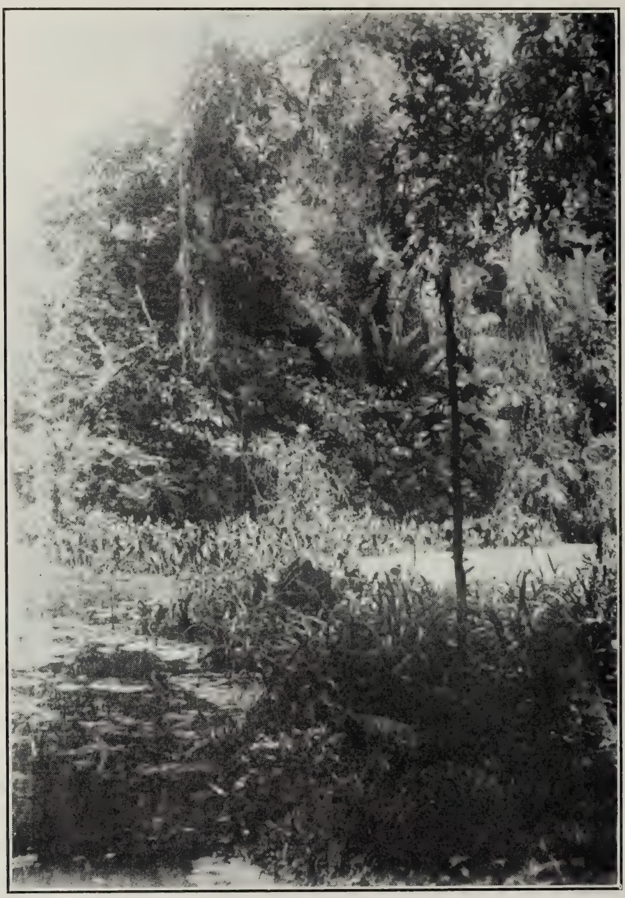


Fig. 11.—A typical lagoon (a river backwater) in new banana land, Costa Rica. The presence of the high-water lagoons often makes drainage operations difficult. The richness of the rain-forest vegetation is also indicated.

a whole was poor. On the other hand, areas were observed where weakly plants prevailed, but where there was little Panama Disease. With regard to the spread of the disease, current theories are not

borne out in Costa Rica, since good plantations of 20 years standing are still flourishing free from disease, but with every chance of infection from surrounding plantations which have suffered from it.

During my second visit to Costa Rica in September, I made a special point of examining the abandoned banana lands. This was part of a visit to the old banana lands of Panama undertaken in order to acquire personal observations on those areas where Panama Disease first became prominent. If one were guided by rumour and hearsay

Fig. 12.—Poor banana land in Costa Rica, where the stunted bananas will soon be smothered by the vigorous growth of a coarse grass.

alone, the inevitable conclusion would be that Panama Disease was responsible for all the abandonments in Central America. The truth of this assertion will be discussed in due course.

My first expedition was to the Siquirres district where some of the lands have been abandoned for the last two to five years after about 15 years of banana production. Here many cases of Panama Disease were observed. As one commonly finds there was considerable variability in the external symptoms, but internal symptoms were of the usual description. One area abandoned for four years was so

grown up in secondary bush that it was necessary to cut a way through. When the soil was examined it was found to be a sandy loam, very mottled and suffering from insufficient drainage. The trouble here, as in many other farms in Costa Rica, lay in the natural compactness of the alluvium, and in the lack of upkeep of the main and lateral drains. These defects generally go with wetness, troublesome grasses, and strong bush. On such soil the root system of the Gros Michel was found to be superficial and horizontal, while roots penetrating the mottled levels were blackened and diseased. Another area had been completely abandoned for the last five years, so that

Fig. 13.—Typical abandoned bananas in Costa Rica, showing the heavy overgrowth of secondary vegetation.

the standing vegetation consisted of the remaining clumps of bananas, secondary bush and grass. The cause of abandonment was lack of production due to poor growth, high water-table, grass and bush, Panama Disease, and in general, bad upkeep. Such an area provides interesting material for the study of the Gros Michel, when it is growing under unfavourable conditions in open competition with the natural weed-flora. Grass smothering is common where conditions make for a slow and lagging growth of the young banana plant. Here I made some observations on the behaviour of Panama Disease. A

remaining clump of fully-grown bananas had a Panama Disease case in the centre, but the surrounding stools were not affected, although the disease had had at least five years to run its course. How did the central stool become affected, and why did the disease not spread to the adjacent stools ? This is but one of the many puzzles with which the investigator is faced in the field.

The following day a visit was paid to some of the plantations near the banks of the River Reventazon. This river brings down quantities of silt from a calcareous region and I was informed that, on the whole, the banana land on its banks was not so subject to Panama Disease. Most of the other rivers deposit an acid silt and disease is more abundant. Again the River Barbilla (a tributary of the Matina) flows through calcareous rocks, while the other tributaries do not. The Barbilla land is said to have but little disease, whereas the other river banks are badly affected. The inference is that soil acidity is a factor which favours the attack of *Fusarium cubense,* while neutrality or alkalinity controls it. In some of the farms visited it was noticeable that patches of disease occurred in open sandy soil, and not to the same extent on good alluvial soil near by. Reports of the occurrence of disease on sandy soils come from many quarters accompanied by the suggestions that acidity, leaching, or rapid propagation of the fungus are possible explanations. This seems a point amenable to experimental investigation.

The farms of St. Louis and Parismino, extensive areas of good dark alluvium, originally under bananas and later abandoned, are now under cacao or in pasture. As far as can be determined by inspection in the field the soil is remarkably good, yet one is informed that this and similar areas were very quickly wiped out with disease from 1912–14. Such soil even though acid should be productive. From observation of this kind one is led to conclude, either that the organism of Panama Disease is so virulent that it will attack the Gros Michel grown under the best of conditions, or that there was a widespread planting of bad and diseased material. For the latter point of view there appears to be a certain amount of justification. It will certainly be admitted that the rapid expansion of the industry coincided more or less with the wide occurrence of the disease. Further, at such times, to acquire sufficient planting material is always a difficulty and much defective stock is pressed into service. As diseased suckers will almost certainly give diseased plants there may thus be an

important outbreak on the best of land. But, unfortunately, on these points we have no exact information, and in Costa Rica it is now impossible to obtain records of this period. If, however, the material planted on these soils was good, then one is left with the impression that *Fusarium cubense* is an exceedingly active parasite and that the genetic constitution of the Gros Michel is such as to make it susceptible under any conditions. A third possibility is that there are adverse soil factors which will only be revealed by careful analysis and experiment.

The next excursion was to the abandoned lands in the Banana River and Estrella Valley districts. Here many of the original Gros Michel plantations have been replaced by cacao, Red Banana and pasture. The land consists of flat stretches of river alluvium interrupted by clay mounds and spurs running down from the neighbouring hillsides. As a result the soil is very variable from area to area, consisting of various river deposits, clay washings from the hillsides and the original weathered soil *in situ*. The reasons for abandonment in this district are not always known, but Panama Disease and various other adverse factors are indicated. It should be mentioned, however, that some of the abandoned lands have been successfully brought back into banana cultivation. In many instances the Gros Michel had been replaced by the Red Banana, and the latter was frequently observed with Panama Disease. This raises the very interesting question of immunity, susceptibility, and the influence of external factors, because the Red Banana, normally highly resistant, may under certain circumstances actually succumb to Panama Disease. In certain areas a kind of leaf scorch was observed in the Red Banana which suggested a functional trouble. There are many ailments which fall into this category. One, locally known as Talia Disease (named after the farm where it occurred), results in the formation of a fruit canker, consequent on a kind of physiological breakdown. No organism was isolated by those who investigated the problem and it was too local in occurrence to merit further attention. In the districts under discussion Panama Disease was very conspicuous but not more so than bad patches due to water-soak and poor upkeep. In some of the properties drainage was noticeably poor, and drains had either never been present, or had long been filled in. In such places it was clear that Panama Disease was by no means the limiting factor. At no point was there a noticeable spread of the disease progressively away from the original infected locality.

Fig. 14.—Flood conditions in the Estrella Valley, Costa Rica. The rivers rise rapidly and cause great damage to plantations, railway bridges and houses.

Fig. 15.—Demolished banana plantation after a flood, Estrella Valley, Costa Rica.

In contrast to these poor areas some very good bananas, of 30 feet or more in height, were seen in a section where a special type of " cleaning " was in use. This consisted in shovelling the ground clear of all vegetation so that the weeds and detritus formed a heap between the rows. The growth was enormous and the output of fruit consistently high. The soil was a very rich deep alluvium close to the river bank, and although superficial drainage was good, the soil was considerably mottled close to the surface. One is led to speculate on the enormous fertility of such land if it were properly aerated even by the minimum amount of tillage. In spite of the very strong growth, close examination revealed the fact that a very considerable amount of Panama Disease was present, and the whole position suggested an interesting struggle between the vigorous growth conferred on the plant by the richness of the soil and the wilting action due to the fungal attack.

Among the many problems and difficulties to be met in these areas are the disastrous floods which cause very considerable damage to crops, bridges and houses.

With regard to the chemical composition of the banana soils of Costa Rica as a whole, Prescott remarks that they are fairly high in iron and aluminium, low in lime and magnesia and in a few instances low also in potash and nitrogen. While in Port Limon I had the good fortune to meet Dr. Reinking, Pathologist to the United Fruit Company. We had several conversations on Panama Disease and banana problems in general, and found ourselves in substantial agreement on most points concerning the present state of banana research.

The results of my visit to Costa Rica may be summarised as follows :—

(1) The banana properties in Costa Rica are so extensive that months would be required even for a general reconnaissance, while a detailed survey of the very diverse soil conditions, climatic and other factors, could only be achieved by a prolonged stay in the country.

(2) It is now very difficult to obtain exact information regarding the history and development of the various banana properties, the reasons for abandonment, the number of years under crop, and so on, as records either were never kept or have been lost.

(3) It is said that there is now practically no farm in Costa Rica free from Panama Disease.

(4) There is much very good land now in cacao or pasture which was originally planted with Gros Michel. This is alleged to have been quickly wiped out by Panama Disease. Whether this was due to the very vigorous parasitism of *Fusarium cubense,* the use of bad material, or some unrevealed soil factor, is not definitely known. It should be mentioned, however, that land planted once and affected with disease was seldom replanted, so that, as elsewhere, there is a lack of sound experimental evidence.

(5) Examples were seen where rather inferior land replanted was absolutely riddled with Panama Disease.

(6) The new land which is being opened up in Costa Rica at the present time is not regarded by those in charge as being of the first class. The main difficulty of the larger fruit companies at the present time is production. About 75 per cent. of the banana properties are privately owned.

(7) In Costa Rica, while undoubtedly Panama Disease is important at the present time, it is not the chief or only cause of abandonment, and probably the same is true of the past. Other important causes are low output due to poor land, high cost of upkeep, water-soak and drainage, grass, bush and bad upkeep. As a rule, however, Panama Disease is made the scapegoat.

(8) In general, agriculture in Costa Rica is still in the preliminary state of broad exploitation and there is little to indicate that the day of more detailed husbandry is at hand.

GUATEMALA.

The eastern banana lands of Guatemala are situated in the humid tropical region of the lower Motagua Valley on the Caribbean coastal plain, with Puerto Barrios as the point of export. The alluvial and hillside soils on which bananas are grown are derived from the complex mountainous hinterland of igneus and volcanic rocks. The large areas of alluvial soil on either bank of the Motagua River have been laid down by a succession of floods, and even when low the river carries along considerable quantities of sediment. This alluvium is very high in silt and clay as a rule, and as a whole the soils are deficient in lime. The rainfall is abundant during a large part of the year, and in its virgin state the banana land was clothed in high tropical rain forest. The export of bananas from Guatemala in 1926 was 5,900,000 bunches.

The banana area* easily accessible by railway consists of flat alluvial land traversed by slow silt carrying rivers. Already there is a considerable acreage under bananas, part of which has been abandoned, but much more extensive areas have yet to be opened up. Some of the alluvial soils of the Motagua River are remarkable. One soil examined consisted of a rich dark alluvium, of such texture as to make for ideal water-relations, and extending downwards uniformly for at least seven feet. Zones of such soil occur extensively on either side of the river ; the latter at this point is fairly broad, slow moving, muddy with its constant burden of silt, and liable to overflow, when large quantities of good alluvium are deposited.

Fig. 16.—The Motagua River, Guatemala. This illustrates the large alluvial flats laid down by river floods—banana land of the future.

The bananas in this section showed strong uniform growth, were free from disease and have proved highly productive over many years.

Drainage operations have been carried out on a very elaborate scale, the ideal being an adequate system of four-foot drains. This brings the water-table down to at least three feet, thereby providing the banana with ideal conditions for sound root development. The

* Visited by courtesy of the United Fruit Company.

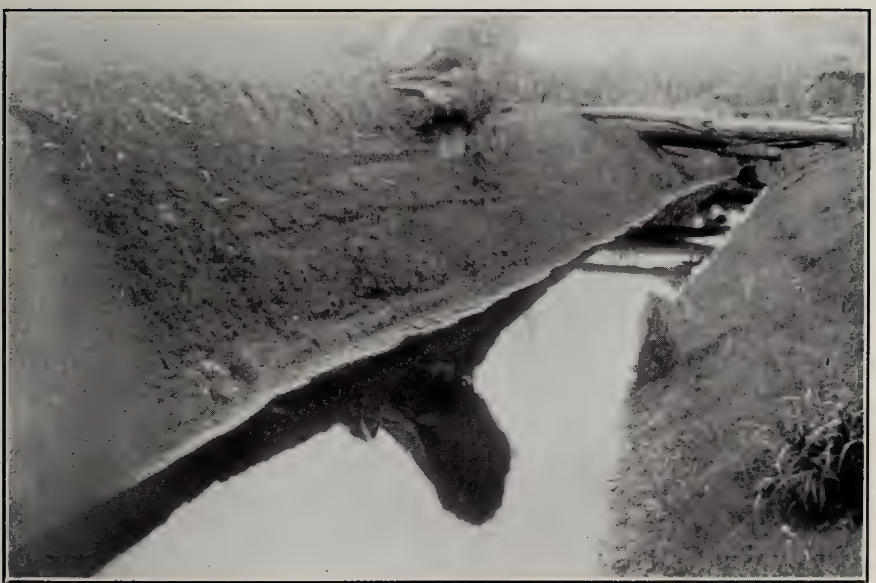
deep main drains permit of detailed examination of the alluvial deposits. The uniformity of the deep loam was surprising, as at all depths the texture permitted of good local drainage. At one point where the contour allowed of bog formation a deep extensive waterway had been constructed to keep the water at a suitable level. Extensive operations such as these, based purely on economic results, are indicative of the high quality and productivity of the land.

My next visit was to an area where felling had just been completed, and where drainage operations were in progress. The felled logs of great size were quickly decaying under the influence of saprophytic

Fig. 17.—A typical area of poor plants suffering from water-soak, caused by high water-table and periodic flooding ; Guatemala.

fungi thereby forming a rich layer of mould on the soil surface. In the absence of functioning drains the soil still bore the marks of long water-logging. The latter is one of the greatest difficulties in this area, and is the chief cause of blanks and poor plantations. I was informed that another cause of blanks in new areas was the use of bad planting material.

Adjacent to the good land just described there were areas which had never been brought into cultivation either because of their boggy



Figs. 18 and 19.—Two examples of the very efficient drainage systems in the banana plantations of Guatemala. These main drains, together with the lateral ones, quickly remove excess water from the uniform deep alluvium.

nature, and drainage difficulties, or because the soil was a stiff silty clay with a tendency to sourness. Originally such areas had been covered with high forest and Cohune Palm (*Attalea cohune*).

At my request a special visit was made to a section where disease and cultivation were at their worst. In some localised spots there were poor stunted patches attributed to soil exhaustion, but in the main, the greatest trouble, and indeed the only cause of defective growth in some good alluvial areas, was water—largely on account of river flooding. Thus in one stand of good plants the river had overflowed to a depth of 3 feet, and had remained so for 10 days at one time and 11 days a little later. The effect of such flooding was :—

(1) to deposit very considerable quantities of high grade silt—agricultural land of the future.

(2) to destroy more or less completely bananas in the inundated areas. The plants had a stunted yellowish green appearance.

(3) to impart to plantations not so badly affected yellow foliage, spindly trunks, and poor growth.

An interesting contrast between flooded and non-flooded land was afforded at one point where the railway embankment served as a barrier. The soil was of the same texture on both sides, but the plantation on the river side was devastated as described above, while that on the protected side supported well grown vigorous plants.

At various points the rich alluvial flats are interrupted by spurs from the neighbouring hilly country. These consist of a red clay, sometimes stiff, cheesy, compact and mottled with yellow and sometimes reduced by weathering to a lateritic condition. In contrast to the high-grade alluvium this red soil is notably poor for banana cultivation, and as experience showed that it only produced for a very limited number of years and was subject to Panama and other diseases, it is now avoided in Guatemala. This type of formation occurs all over Central America, and I have observed that if planted in bananas it consistently goes out after a very few years. Geologically it is associated with the rolling hilly formation, and represents a soil of a stiff adhesive nature which does not readily succumb to denudation. The acidity attributed to these soils is in contrast to the alluvium deposited by the Motagua after its passage through limestone country.

All the alluvial flats in Guatemala, however, have not proved equally successful as banana propositions. In some sections there are large areas which have proved unproductive, and have been

abandoned on account of Panama Disease, soil sourness, and difficult stiff clay texture. At the present time these areas support secondary bush of an inferior kind. A soil inspection revealed a highly mottled clay soil on the surface, to a depth of 3 to 6 inches ; underlying this was a sticky blue clay which undoubtedly exercises a toxic effect on the roots of the Gros Michel. Such areas were mostly adjacent to the hills. Further, on examination of the neighbouring streams and creeks it was found that these were running clear on a stony or gravelly bottom. The obvious inference is that this area has been subjected to considerable denudation. The useful alluvial materials have all been washed off and transported down stream leaving behind the more resistant clays of the hill formation.

Arapahoe Farm, some 53 miles from Puerto Barrios by rail, lies close to the Motagua and is of especial interest. Originally this land was abandoned on account of inundation caused by the overflow of the Motagua. The soil was a very good sandy alluvial silt, however, had originally supported very big timber, and seemed eminently suitable for bananas. At very considerable cost a levee to exclude the overflow of the river was built, and as a result a very large area of rich land was made available for bananas. At the present time this land is in a very high state of production with very little Panama Disease.

With regard to the occurrence and spread of Panama Disease the following points were noted :—

(1) On the good open alluvial soils there are few cases of Panama Disease. Some of these have been under observation for a number of years and no spread of the disease has taken place.

(2) Resistance to Panama Disease has been observed on both alluvial deposits and clay soils.

(3) The abandoned areas are mostly on red clay, hilly land, brown mottled clay, and in general on soils that are not of the first class.

(4) At the present time areas of poor bananas are mostly due to flooding and high water-table rather than to Panama Disease, and banana losses are often due to the choice of unsuitable land in the first instance.

(5) The most severe attacks of Panama Disease took place on the red clay lands. The durability of such soil is limited to some 5–10 years. On this subject Prescott mentions that of seven

samples in which marked silt deposition takes place, six have had an excellent cultivation history ; while of twenty-three samples in which there was no silt deposition only thirteen have a good history. Good cultivation history has been found to coincide with good soil texture.

(6) Abandoned areas have been brought back by suitable attention.

(7) Guatemala has still many areas of good land suitable for banana production.

BRITISH HONDURAS.

British Honduras, the only British colony in Central America, lies in the South-Eastern corner of the Yucatan peninsula, between the latitudes of 15° 53′ and 18° 30′ North. At the present time the colony supports but a scanty population and much exploration must yet be done before its possibilities can be accurately assessed. With the exception of forestry, there is a great dearth of other scientific knowledge regarding the colony ; this is reflected in the fact that an agricultural officer has been appointed for the first time during the present year.

The climate is sub-tropical and humid, the country is intersected by many rivers, and the vegetation is rich and varied.

The output of bananas from British Honduras is small, the total for 1926 being only 161,281 bunches. Hitherto the industry, located mainly in Stann Creek Valley, Riversdale and Monkey River, had produced about half a million bunches per annum, but this has declined considerably on account of Panama Disease and other difficulties. The major operations were commenced in Stann Creek Valley about 1907–1908, when broad scale plantations of Gros Michel were established as in Costa Rica. At the same time a Government railway was built to carry the fruit down for export. Unfortunately the venture did not meet with the success that was expected and attention is now being given to the extension of other industries to replace the banana.

Stann Creek thus presents an interesting field for the pathologist, and during my brief visit I was able to make a number of observations which throw light on the banana situation there. The several excursions were made in company with Mr. J. N. Oliphant, Conservator of Forests, and members of his staff.

After leaving the pier at the marine terminus of the railway, one passes through a long region of mangrove. This consists of uniform flat country, mostly standing in brackish water and supporting a characteristic vivid green bush vegetation. Farther along the line, where the land is high enough to be reclaimed there is a mixed cultivation carried on by a moving peasantry. Some small banana plantations observed at this point were obviously suffering from a high water-table, and bore the characteristic symptoms in spindly uneven growth, with much leaf discoloration ; there were also cases of Panama Disease. This land was little more than reclaimed and the hollows all contained standing water. The soil of a yam bed close by was examined ; the surface soil appeared to be very good, rich in humus and of good texture, but about 4 to 6 inches down there was a quick change to a peculiar light yellow soft micaceous sand.

As we proceeded up the Valley other bananas were observed, many of which displayed some defect in general growth and vigour. A plantation near a limestone quarry was examined in some detail. This area, evidently at one time a bog or pan of some kind, had been recently reclaimed by drainage and planted with bananas. Some of the plants were making a strong growth, but on the whole the plantation was very uneven, indicating lack of soil uniformity or unsuitability of some kind. The soil was of greyish white colour, very close and compact in texture, and obviously in the need of aeration. Here the defects in growth had probably resulted from planting too soon after reclamation. A neighbouring area supporting much better bananas had soil of a much loamier nature. Forest soil nearby consisted of a dark loam, well supplied with leaf mould, underlaid by a yellow clay subsoil.

Farther up the valley an interesting riverside area was examined. This had supported bananas from 1911–1918, abandonment being attributed to Panama Disease. It had been allowed to go back into secondary bush, and during the present year it had again been cleared for bananas. Drainage was good and the young supplies were growing very vigorously. The top soil, on examination, was found to be a very open gritty sandy loam, at present well supplied with vegetable mould. It was underlaid by a gritty gravelly subsoil. Such soil and subsoil undoubtedly make for admirable rooting of the Gros Michel, but in a country of heavy rainfall, leaching of the essential minerals must be very rapid, while the humus supplied by the secondary bush will soon

be depleted. Thus, a soil of this kind shows two contrasting characters, namely, great fertility in its virgin state, and rapid exhaustion under single crop exploitation.

The 25-mile railway line terminates at Middlesex, an area originally planted up with Gros Michel, but soon abandoned on account of disease. This area showed a considerable variety of soil types, including a gritty yellow clay, deeply weathered, a red soil of the type seen in Guatemala, and an alluvial yellow brown silty clay. This variation is not surprising when we consider that this is the point where many of the tributaries meet to form the main stream, and also where the plain and hillsides meet. The red soil, of fairly extensive occurrence, had been weathered at several points to something resembling a laterite ; it has already been mentioned that such soils are avoided for banana cultivation in Guatemala. This formation was not alluvial in nature but appeared rather to consist of the original hillside material, weathered out *in situ* by the high rainfall. This type merged into the yellow clay—a resistant soil occupying the areas between the many streamlets, and as a result washed free of all the coarser and more friable materials. The valley bottom near by consisted of a stiff compact silty loam, probably acid, but with good qualities if suitably treated. In its present untilled state the compact texture would oppose root development. Surface drainage in these areas appeared to be good. An examination of the streams showed that these flowed clear and free of sediment over stony and sandy bottoms. The whole area of Middlesex has many springs and streamlets whose headwaters lie not more than 5 or 6 miles distant.

Other soils observed were poor and gritty, and would very soon be depleted of their foodstuffs. In one area an interesting soil profile was noted ; it consisted of a good surface loam, 4 inches deep, immediately overlying a silty yellow clay, the transition being clearly defined. The clay subsoil which had been thrown out of the ditches some two months before still remained unpopulated by the adjacent weed flora, indicating the presence of some markedly toxic substance.

In presenting these observations on the soils of Stann Creek it is not claimed that anything in the nature of an adequate field survey was made. There are, however, certain inferences which cannot be overlooked, especially in relation to broad scale agricultural exploitation. These may be briefly discussed as follows :—

(1) There are no extensive areas of ideal banana land in Stann Creek, and the soil, instead of being uniformly good as is usually thought, is, on the contrary, very variable and often poor. The various soils examined fall into two main categories :—

(*a*) Soils consisting of large particles, mainly coarse sand and grit. These are alluvial and have been left behind when the finer materials were washed down stream. If well supplied with humus they support remarkably good growth. This does not continue over many years, however, because the humus soon disappears, and the high precipitation causes extensive leaching. At the present time these soils occur in the loops of the meandering streams ; they give very good results the first year or two after planting but soon deteriorate when kept under a single crop with no attempt at humus conservation.

(*b*) In the second category are soils of a stiff compact nature which have been washed bare of all the more open and friable surface materials. Their cohesion and fine texture have enabled them to resist the violent denudation consequent on high rainfall. These soils are mostly found near the head of the valley, or on the hillsides flanking the river.

Thus, as Stann Creek is not a broad valley, the extent of alluvial soils of good texture is limited, and the general field evidence seems to indicate that the best potential soil material has been washed down the valley and deposited in the mangrove swamps or in the sea, leaving behind either coarse materials or stiff compact clays.

(2) From the brief examination described above it is clear that Stann Creek by no means shows a uniformity of soil type. In point of fact there are several soil types which quickly pass one into the other, thereby presenting considerable variation in field conditions. But, at the commencement of banana cultivation this does not seem to have been recognised, and following the general mode of procedure in Central America, bananas were planted broadcast. Considering the lack of soil uniformity, the absence of extensive areas of good banana land, and the presence of Panama Disease, the decline of the industry is scarcely surprising.

(3) The good banana land consists of alluvial soil ; some of the best is found in the triangular areas where the river forms a loop provided good drainage can be achieved. Thus a soil explorer following the river and not gauging the proximity of the clay hillsides might be misled into the belief that the potential banana land was extensive.

(4) Successful banana growing in Stann Creek will depend on the careful selection of the comparatively limited areas of suitable land. Taking the valley as a whole detailed agricultural reconnaissance and careful husbandry will be necessary to ensure anything more than transitory success.

Another visit was made to the Sibun River. At the mouth of the river there is the characteristic long mangrove belt, which gradually rises to an area where the soil consists of a stiff silty clay. This supports good sugar cane (peasant cultivation) but is not suitable for bananas. Higher up the valley are areas of Pine Ridge, sand and savannah—both probably highly acid, judging by the vegetation. On the whole, open loamy deposits appear to be localised and inextensive.

The soils of the northern plain of British Honduras (Northern River district) are calcareous marly clays. A certain amount of banana growing is carried on in this district, and I was informed that there was little Panama Disease. Unfortunately I was unable to make a visit to Northern River and therefore cannot supply data for contrast with Stann Creek.

The general impression of a visit to British Honduras is that a soil reconnaissance is desirable before further embarking on any large scale agricultural project.

JAMAICA.

During my visit to Jamaica in July and August, I was able in company with Mr. F. E. V. Smith, Government Microbiologist, to visit most of the important banana growing districts and to observe the many aspects of cultivation. Jamaica has been described as an island of samples and this remark is applicable not only to the variety of soils on which bananas are grown, but it is also true of the many forms of cultivation. It is not proposed here to give a detailed account of the many aspects of the banana industry in the island. That has already been set out in Fawcett's book (The Banana) which covers all the major field operations practised in Jamaica at the present time.

The history and the present position may be summarised by the following two quotations :—" In the early stages of the industry in Jamaica, ' banana land ' was accepted to mean a soil in which without drainage, without tillage, and by a superficial process of clearing and, perhaps, burning before the suckers were planted, a good yield of commercial fruit was obtained by the grace of Nature alone " ; .... and " If the working basis of the latest and most progressive cultivators be regarded, it would appear that a ' banana soil ' and a ' cultivated soil ' will soon be synonymous in Jamaica." Thus in the production of bananas, Jamaica stands out in sharp contrast to Central America. It has long since passed through the preliminary stage of soil exploitation and has now a deep rooted agricultural tradition with labour trained to detailed field operations.

The active interest which was taken in Panama Disease from the very outset in Jamaica soon materialised in the form of Plant Protection regulations. In 1910 a proclamation was issued forbidding the import of any portions of banana plants or labourer's implements from Central and South America and Trinidad, and during the following year a Diseases of Plants Law became operative to deal with possible cases of Panama Disease. The field measures adopted to combat the disease were most drastic and involved the destruction of all plants within a radius of one chain from the original infected plant. Since then the quarantine area has been reduced and in some parishes a " nine-root " treatment is the rule. In the writer's opinion this should be replaced by a " one-root " treatment to destroy infected material and prevent its use for replanting. As far as the merits of the quarantine regulations are concerned, when it is considered that *Fusarium cubense* can grow and spread through the soil it is obvious that the present " nine-root " treatment does nothing to destroy or control Panama Disease. Financially, the destruction of plants under the quarantine does nothing but magnify the loss.

At the present time there are many false ideas afloat regarding the virulence of Panama Disease. During my visit areas of good land were pointed out to me which were described as " abandoned on account of Panama Disease." Enquiry into the number of cases and the acreage showed, however, that there had been perhaps five or six cases per acre, i.e. five or six diseased plants in 350, or about $1\frac{1}{2}$ per cent. of actual disease. Now it must be recognised that this small percentage of disease cannot be regarded as *virulent*. It is true that there are a few areas where 10 per cent. of diseased plants have been found, but examination of the area showed that in all probability

it should never have been planted in bananas at all. Examination of the records, however, show that many areas of good land have been abandoned on account of a very small amount of actual disease.

In a report submitted to the Acting Governor of Jamaica in August, the following suggestions were offered for consideration :—

" (1) The present quarantine regulations entail considerable expense on the part of the Government, and cause considerable loss to the planter in respect of treatment, loss of land and fruit. From the point of view of modern fungal and soil science, the nine-root treatment does nothing to stop the spread of the fungus. It is suggested, that, at a suitable time, *the nine-root treatment should be replaced by a one-root treatment.* There is everything to be said in favour of a one-root treatment as it prevents the use of infected material.

" (2) If Panama Disease is cured it must be cured by treatment capable of simple agricultural application, and within the economic limits of the industry. All the evidence suggests that the disease is associated with lack of fertility and adverse soil conditions, such as acidity, bad aeration, water-logging, shallow soils, presence of toxic subsoil, etc. Each soil must be treated according to its own special requirements. As we are at present in a state of ignorance, due to lack of experimental evidence, regarding the conditions which make for the attack of *F. Cubense, it is suggested that greater freedom and scope be given for the purpose of carrying out critical experimental work in connection with progressive soil improvement and the treatment of diseased areas.* Of course it will be said that such work has been carried out with no result, but there is no published or other evidence to show with what accuracy or critical care the experiments were carried out. Unless the experiments are carried out under properly controlled conditions, they are useless. It should also be pointed out that such experiments are not of the ' hit or miss ' variety. Every experiment brings some new knowledge and while the disease may not be absolutely eliminated by sound agricultural treatment, it may be held in check to such an extent as to be no longer a menace.

" (3) It is suggested also that a constructive policy should be adopted with regard to improvement of agricultural methods, such as deeper cultivation either by fork or by the use of up-to-date implements, the appropriate use of lime from the many

sources of good lime throughout the island, and the conservation of soil humus by the use of cover crops. If some of the present expenditure on Panama Disease were directed into these channels, there is a strong probability that Panama Disease would be held in check, while the whole agricultural industry of the island would benefit by the better husbandry and improved soil fertility which would result."

In Jamaica very considerable progress in the practice of agriculture has already been made, but there are still many instances of good land which would be greatly improved by suitable treatment. On the other hand, there were several instances where considerable insight was being shown in the making and treatment of soils, in the opening up and improvement of land, and in the use of lime and cover crops.

COLOMBIA.

To the investigator of banana problems, Colombia offers very considerable interest. Since the first recorded export of about 172,000 bunches in 1892, the industry has expanded as follows: 1,397,000 bunches in 1906; 4,902,000 bunches in 1911; and 10,870,000 bunches in 1926, when Colombia ranked as third in the banana producing countries of the Caribbean.

The banana land of the Santa Marta district of Colombia consists of an alluvial coastal plain, whose soil derived from the Sierra Nevada de Santa Marta has been transported and deposited by a number of parallel streams. The alluvial materials vary from gravels and coarse sands to very fine silts and clays. Chemically the soils are sound, being adequately supplied with all the essential minerals (with the exception of Nitrogen in some instances), coupled with a high lime content. The rainfall is limited and during the dry periods irrigation is the rule. Colombia is unique in that the occurrence of Panama Disease there has not been reported. Lastly it should be mentioned that good plantations of the Gros Michel have been established on a wide range of soils, from coarse sands, with very little binding matter, to fine silts of good physical texture. In many areas the soils are very good and suitable for bananas even without cultivation. This may be attributed to their good physical texture, the adequate lime content, and to the open sandy subsoil found in most districts. Yet, in Colombia, as in Central America, there are considerable areas of abandoned land and that even in the absence of Panama Disease. On the whole, the field problems appeared to the writer to be of a fairly direct nature. They include, in order of importance, high water-

table and drainage, soil aeration, and salting. Other difficulties are concerned with the maintenance of irrigation water, while the major calamity is undoubtedly the occurrence of an extensive "blowdown."

Colombia offers favourable conditions for studying the effect of bad drainage and water-soak on the growth of the Gros Michel, especially as the added complication of Panama Disease is absent. In one section a large area had, at one time, been abandoned on account of adverse conditions, but this has proved to be simply a case of drainage and already half of this area has been reclaimed. Here direct observations on water-soak can be easily made, because all gradations from bog conditions to well drained soil occur in close proximity. Typical uncomplicated water-soak in Colombia produces characteristic effects, to wit :—(*a*) the whole plant is stunted, (*b*) the leaves are of pale-green fading to dull yellow, sometimes with streaks along the veins, (*c*) the leaf-blade often breaks through halfway, (*d*) no Panama Disease symptoms external or internal, are present. Where a plantation dips to a water-logged hollow a gradation from tall healthy plants to dwarfed discoloured ones is the rule. Soil examination revealed good texture and suitability to strong root formation. Reclamation consists in opening up existing creeks, excavating broad drag-line ditches, and digging lateral drains so as to bring the water-table to at least three feet below the surface. Water-logged areas are easily recognised by the distinct semi-aquatic vegetation which they support.

Second in importance to drainage, and, indeed, directly related to it, is the problem of soil aeration. Soils of coarse texture or those which have long had adequate drainage need not be discussed at this point. They mostly prove fertile and consistently yield good fruit. There are considerable areas, however, where the soil is in distinct need of stirring and ventilation, the absence of which adversely affects the growth of the Gros Michel. A typical soil profile frequently observed was as follows :—on top there was a foot of grit, loam or soil of fairly good texture ; this was underlaid by a blue clay-like stratum, while at 3½ to 4 feet down an open sandy layer was usually found. In various sections bananas had been planted on such land, and as a rule they showed poor lagging growth, a stunted appearance and bad colour ; sometimes the plantation failed completely or took 20 to 24 months to fruit instead of about 12. The major difficulty was fairly evident. When the planting material is set in the usual 15-inch hole, the young roots come almost immediately into contact with this stiff impervious unoxidised clay. The result is that they are usually

blackened and killed. In its original state the blue stratum has a clay-like plasticity, and it is often highly mottled with red ; if it is exposed for a few weeks, however, it undergoes a remarkable change. It weathers very quickly, there is a rapid colour change to brown, the gummy character disappears, and when crumbled between the fingers it is found to be in reality a fine silt. The highly coloured appearance and clay-like plasticity have evidently been imposed on the material by long compacting under water. During the weathering of such material it is clear that many important chemical changes are set in motion. What these are is not definitely known, but they are probably referable to the broad category of oxidisation. Many field observations indicate clearly that both in its original state and while the first stages of weathering are in progress, this stratum is distinctly toxic to the newly formed roots, thereby involving a general depression in all the growth activities of the young plant. Such land should obviously be prepared before planting.

Another field, examined in some detail, had been planted only one month after the completion of drainage operations. Practically all the young plants had a stunted yellow appearance, accompanied by a leaf scorch suggestive of chemical defects. Suckers dug up had a soaked appearance and were rotted and invaded by various putrifying organisms. As a rule the sucker was found to be absolutely encased in blue clay. Roots which had penetrated the clay were blackened and killed as if by toxicity, so that the general effect on the young plant was that of root failure and chemical injury. Where open drains occurred, however, it was found that this clay weathered out to a silty soil of good texture. Field experience shows that these soils slowly improve, but it is a question if, in the absence of adequate stirring and ventilation, they will reach their maximum productiveness for a long time. The best results will undoubtedly be achieved by ample aeration before planting.

The areas which have been abandoned on account of " salting up " occur in the Rio Frio district. This land, consisting of a remarkably good, free loam, lies only a few metres above sea level and is in moderate proximity to the coast. The area, arid in its natural state, was planted with bananas, but irrigation was insufficient and drainage was poor. After some years, by the concentration of salts at the surface, due to high evaporation and inadequate leaching, the land became " salted up " and banana cultivation has gradually receded. On inspection the soil texture was found to be excellent ; but on the

surface there was a powdering or caking of soluble crystals to such an extent that the only persisting vegetation consists of typical halophytes, including samphire, mesquite, and other leathery leaved and prickly plants. Farther inland where bananas still persist, the effect of salt land was seen in a general stunting of the plant accompanied by a dull-coloured marginal withering of the leaves culminating in a dead brown. There was no leaf breaking, and in general the appearance was that of chemical scorching. Similar areas of banana land in Jamaica were also abandoned on account of salting and this was again due to the absence of ample irrigation water and of suitable drainage. Such land can gradually be reclaimed by leaching given sufficient water and adequate drainage.

The incalculable factor in Colombian banana production is, of course, the blowdown. This is purely local in occurrence. It is the result of a violent wind storm generated in the hills, which, sweeping down on the plain causes a great deal of curiously localised damage. During my visit in August, following a blowdown, I was able to make observations on the damage sustained. The noticeable feature was that most of the destruction consisted in a snapping of the trunks, and not in a total uprooting of the whole plant. The latter is another indication of the general soil character which, for the most part, is of such a nature as to allow of good root development.

These observations touch on but a few of the many interesting banana problems of Colombia, a country of great interest and undoubtedly of great possibility.

PANAMA.

In Panama, the modern banana industry, as in other Central American countries, began about the opening of the present century. For many years bananas have been the chief export and even at the present time, although production has greatly decreased, they still take first place among the country's natural resources ; thus of a total export trade of 3,530,800 dollars, in 1925, bananas were valued at 2,165,150 dollars. The original industry was centered at Bocas del Toro, but at the present time fruit is also grown for export in the Canal Zone, and in the San Blas district (East of Cristobal), while new areas are being opened up at Armila on the Caribbean Coast, and in the Chiriqui province on the Pacific.

Panama Disease was first recorded from Panama in 1903. A few years later it had caused great havoc there and also in Costa Rica. By 1920 several areas of 15,000 to 20,000 acres had been abandoned.

In 1926 alone a total area of 4,538 acres of Gros Michel land was abandoned, and it was estimated that a still larger area would go out of cultivation the following year. This country is, therefore, of the greatest interest to an investigator of Panama Disease. Popular accounts generally attribute to these lands enormous fertility and ideal conditions for uniform large scale production of bananas, while Panama Disease is regarded as the scourge responsible for all failures. To endeavour to assess the veracity of these ideas, and to obtain definite personal impressions the writer made a special visit to Panama in October.

The Changuinola District.—The original banana industry of Panama was centered at Bocas del Toro, from which fruit grown round the Chiriqui Lagoon and Almirante Bay was exported. The present centre, Almirante, lies on the mainland ; it has a well-founded United Fruit Company colony and is responsible for handling all the fruit produced in the Changuinola, Sixaola, and Talmanca districts.

On leaving Almirante for the Changuinola district* the railroad runs parallel to the coast and passes through low-lying bush country, partially occupied by small settlers who grow a limited amount of bananas, cacao, and household crops. The land is undulating and out-crops and cuttings reveal the presence of characteristic red and yellow clay.

Large scale production is first encountered in the vicinity of the Changuinola River. At this point the stream is broad and meandering, with many backwaters and lagoons. The large, approximately square, area through which the river passes—known as the Changuinola Division—is a great alluvial flat, very little above sea level, and subject to frequent inundation. At one time it was extensively planted in Gros Michel, but now, with the exception of a few outlying small farms near the hills, it has been completely abandoned for bananas, and has been replanted in cacao and coco-nuts, or left as pastures. The latter present broad and picturesque vistas. At the present time the cacao is not so good as it might be, and in general suffers from close planting and too much shade. Coco-nuts have been planted but with no great success ; they show defective growth and are subject to several diseases. Thus, at the present time, one can pass through practically the whole of the large Changuinola Division without seeing a plantation of Gros Michel.

* By courtesy of the United Fruit Company.

Soils of some of the cacao plantations were found to be of good silty loam, and, I was informed, remained in good condition in spite of the heavy rainfall. Other soils examined were decidedly mottled. The whole of this area is subject to great leaching on account of high rainfall and flood. To generalise on the nature of these soils, however, is both difficult and inaccurate, since they have been laid down under varying conditions, by a river whose course has frequently changed during the formation of the alluvial plain. Changes in the direction of the river from time to time are reflected in the presence of many backwaters and lagoons. These may exercise a considerable influence on the surrounding district.

Fig. 20.—View from above of the Changuinola River and one of its tributaries, Panama. The flat alluvial banana land has been deposited by the successive floods of the Changuinola.

This extensive area, now well supplied with railroads, was felled and planted in the usual way, and it appears that most of the farms gave about 12 years of fairly good production before the major troubles set in. As far as the records go, they indicate that on those farms where general growth and production were good the rate of spread of the disease was slow. Where cultivation and production were poorer the disease is usually reported as having spread rapidly.

From the incomplete information gleaned on a brief visit, many conflicting pieces of evidence emerge, and it is necessary to disentangle and evaluate the many contemporary incidents as far as possible. Thus, as pointed out elsewhere, in the rush to open up large areas, diseased material was often planted on the best of land, but of course, with the lapse of time and change of *personnel* it is now impossible to estimate the extent and significance of such procedure. Another aspect, however, emerges from a study of the available records when

Fig. 21.—A picturesque backwater in the Changuinola banana country. During floods the river frequently changes its course, thereby forming lagoons and backwaters which influence the adjacent country.

read in conjunction with some knowledge of the behaviour of virgin land under a single crop. On many farms Panama Disease had been recognised for a long time. Its spread was noted as being slow or very slow. Then, after the land had been constantly under bananas for 10, 12 or 14 years, the disease is reported as having spread very rapidly. In the light of these observations it is clear that the spread of the disease presents two distinct facets, namely, the slow spread

Fig. 22.—Giant trees left standing in a newly opened plantation. Panama.

while the soil is still strongly influenced by its original virgin condition, and the rapid spread after 10 or more years when the original soil status has been greatly modified. Already there is a body of information which points to the fact that, with the exception of certain soils of remarkable staying fertility, a rapid deterioration is induced by single crop exploitation of virgin soil in the absence of cover-crops, rotation, cultivation, and general maintenance of food supply. The exact nature of this deterioration has not yet been determined. The general biological observation is, however, of some value. A soil originally supporting giant rain-forest trees, when planted out under a single crop for years on end must undergo marked modification. For the particular crop in question the soil appears to have decreased in fertility. In the writer's opinion this is an aspect that deserves attention in any discussion of large scale abandonment. It may be a factor that operates alone, or it may work in conjunction with the parasitic activity of soil organisms. Thus abandonment may be attributed simply to an accumulation of the specific parasitic organism in the soil, or it may be associated with factors which begin to operate when important departures from the original condition of the virgin soil have taken place.

The remaining banana farms in the Changuinola Division are privately owned. They occur on the outer margin of the large plantations and occupy areas which were formerly rejected for banana growing. One of these was visited and was found to be rapidly degenerating, yet only some five years ago it had been virgin land and had produced well for the first few years. Panama Disease was an important source of loss, but the irregularity of the plantation was further accentuated by water-soak caused by the high water-table. The soil, a silty loam, was found to be badly mottled, while the general upkeep was negligent. The abandonment of such a property would be attributed to Panama Disease, but, while the latter is undoubtedly significant, there are clearly other equally important adverse factors at work. Another small plantation privately owned had recently been opened up on the edge of untouched virgin forest. Here one was able to observe the enormous stature of some of the trees. On penetrating into the forest it was found that, owing to the shade, there was very little undergrowth ; a soil profile showed surprisingly little surface mould, while the influence of humus was decidedly limited.

A visit was next made to the collection of banana and abaca varieties belonging to the United Fruit Company. This large and

interesting collection was made with a view to breeding an immune variety to replace the Gros Michel, but so far nothing of direct commercial value has resulted. The collection is planted on land badly infected with the Panama Disease organism, and in contrast to the immune varieties the susceptible ones can be seen at a glance. Thus one is led to recognise the fact that, while there may be some external soil condition which militates against the resistance of the Gros Michel, the land is yet sufficiently fertile to support good stands of other varieties. Such observations are indicative of the importance of genetic constitution.

Fig. 23.—A characteristic view of the Sixaola River (Panama–Costa Rica). The river meanders across the plain, forming flat alluvial stretches by a succession of silt depositions.

The Sixaola Division.—On the way from the Changuinola to the Sixaola district the railway passes through the San San Swamp. This is an extensive area of low-lying land, covered with aquatic vegetation, and sometimes flooded to such an extent that the railway becomes impassable. Bananas growing in the vicinity of the swamp exhibit the adverse effects of the high water-table.

After crossing the San San swamp the railway proceeds to Guabito, a large Fruit Company settlement, which serves as the centre for the activities of the Sixaola Division. The latter is an extensive area, and includes plantations on both the Panama and Costa Rica sides of the Sixaola River.

A visit was made to one of the few remaining banana farms on the Panama side. This had been planted out in 1919 on virgin land and had produced well until 1923 when rapid deterioration set in. Since then it has been completely abandoned, and is now in rough pasture.

Fig. 24.—A large stone embankment constructed at a bend of the Sixaola River to prevent a change of course and the consequent flooding of cacao plantations.

As usual it was attributed to Panama Disease or " disease." Examination revealed several interesting points :—

(*a*) The top soil was in bad condition, being lumpy, hard and baked ; it also suffered from shallowness.

(*b*) The subsoil was a sticky mottled clay.

(*c*) The water-table was high.

(*d*) The secondary vegetation was semi-aquatic, consisting of characteristic grasses, sedges and aroids.

In other areas of this farm where bananas were still growing, or where abandonment was of recent date there was evidence that water and bad maintenance were factors for abandonment in addition to Panama Disease. The soil was again mottled and in poor condition with a highly impervious subsoil.

In the Sixaola North Division (Costa Rica) the river is sinuous and meandering while flooding, bursting of banks and changes in the whole course have not been infrequent. On passing through this section of country one encounters many lagoons, creeks, backwaters and dried-up river courses. As a result of this type of river action

Fig. 25.—An abandoned area, Sixaola Division. The land has been allowed to go back into secondary bush and grass, and only occasional clumps of bananas remain.

the soils are exceedingly varied. They include all grades of alluvial material, in different combinations according to the mode of deposition, and to the nature of subsequent flooding. There is thus no uniform alluvial soil over this section and the variation in the vegetation from area to area may be taken as indicative of the many different growth conditions.

Taking this region as a whole the farms generally lasted from ten to twelve years, after which they were abandoned on several counts.

At the present time practically the whole area is in cacao—an enterprise which has not yet proved very profitable. Generally surface drainage is good, but local drainage is poor on account of the compactness of the soil. This is now being improved by the growth of a leguminous tree used as a shade for cacao.

It is a strange fact that one may now pass through this large division and only occasionally see small plantations of bananas. One of the remaining cultivations, the property of a small fruit company, was visited. The plantation was found to be poor and uneven, and

Fig. 26.—Abandoned bananas overgrown by secondary vegetation. After a few years the bananas practically all disappear, and are replaced by a rather poor type of secondary bush. Sixaola Division, Panama.

the fruit mediocre. The soil was a sticky marl-like clay, low in humus, and as a whole of distinctly poor quality. Panama Disease was fairly abundant. A newly opened section, some eighteen months old also showed very indifferent growth. The humus of the virgin forest had only influenced the soil to a depth of about 2 inches, below which was an intractable sticky clay. Under these conditions the slow uneven growth of the plantation was not surprising. This, however, is but one of the many instances where cultivation has been attempted on

unsuitable land. Such a plantation will inevitably be abandoned in a few years. Fruit, however, is so scarce that any production, no matter how fluctuating, is acceptable.

In contrast to these conditions on clay land, another area was inspected where Lacatans were being used as a shade for cacao. The soil was very poor and gravelly and the resulting growth was feeble.

On the whole, the Sixaola Division is much less uniform than the Changuinola Division. Enough has been said to indicate that the uniform fertility attributed to these two districts does not represent the whole truth.

Fig. 27.—Final stages in the disappearance of bananas in abandoned areas. The stools are smothered by grass and are finally overgrown with vines. Panama.

The Talamanca Division.—After the abandonment of the Changuinola and Sixaola Divisions for banana growing, the Talamanca Division was opened up. The major operations began about 1920. Before then only a few private planters had occupied land in this area, but the pressing need for fruit led to large scale operations in this outlying section. Already many of the plantations have been abandoned, and indications are not lacking that the whole Division

will soon share the fate of Changuinola and Sixaola. But this is not surprising, since much of the land is quite unsuitable for large scale production, while the nature of the country is such as to make for high overhead expenses.

A few observations on the nature of this country will make matters clear. The whole area lies close to the hills and is greatly dissected by many streams. These are swift flowing, and with the high rainfall and drainage from the hills they rise quickly and cause important

Fig. 28.—A typical example of the many dried-up river courses in the Sixaola Division. The country, far from being uniform has been formed under a variety of conditions.

floods. The result after long and continuous erosion is that most of the friable sandy and silty materials have been carried off and deposited in the alluvial flats lower down, leaving behind only the more resistant and intractable clay soils, or gravels and grits. Thus the soils of Talamanca are both varied and poor. Here and there good pockets occur, which, planted up originally, gave satisfactory results and suggested that Talamanca might prove to be good banana country. It appears that extensive field operations were commenced

with only a meagre preliminary soil exploration. On several counts it has proved a very unsatisfactory division. As a result of the divided nature of the country road-making and bridge-building are heavy oncosts, while the rapid floods are a cause of constant destruction of bridges, whose upkeep is expensive out of all proportion. These, together with the short-lived nature of the plantations, militate against the success of this enterprise.

Some areas were quickly affected with Panama Disease, others were so little suited to the Gros Michel that the plants grew badly and did not even shoot. As indicated above the most productive soils are found in localised pockets. Such an area is clearly more suited to detailed working by small owners or a localised peasantry than to large scale uniform exploitation.

The Canal Zone.—In addition to the production of bananas in the Province of Bocas del Toro, the larger fruit companies also purchase and ship fruit from Cristobal. This is grown round the Gatun Lake, and in the San Blas district to the east. This enterprise is a result of the scarcity of fruit consequent on the large abandonments described above.

The banana-growing areas in the Canal Zone are situated round Gatun Lake and along the upper reaches of the Chagres River. These plantations are small and localised and for the most part are only accessible by canoe or motor-launch. Most of the fruit is rather small and of indifferent quality, but for want of better is actively competed for by different companies, an important factor being the possession of a fleet of suitable launches and barges. Through the kindness of the United Fruit Company I was able to make observations on plantations on the shores of Lake Gatun and along the banks of the upper Chagres River.

At the present time banana-growing round the shores of Gatun Lake presents some rather unusual features. On account of the impounding of the Chagres River in Gatun Lake to furnish water for operating the locks of the Panama Canal, cultivation is now of necessity limited to the high ground and hilltops which rise above the new water level. Most of the plantations occur on the typical red and yellow clay soil common to many of the low hills of Central America. For banana-growing, as pointed out elsewhere, this soil is distinctly poor. Consequently, the plantations are short-lived, and

after producing for four to seven years they are allowed to go back into bush. Panama Disease is of frequent occurrence and is scattered through all the plantations.

The average farm, of about twenty acres, is rented cheaply by a peasant proprietor. Plantations occur here and there on islands (hill-tops), valley tops, and hill-sides. There are many of these round the Lake so that the total collection of fruit lies between one and two million stems per annum. The general upkeep is bad, little bushing is done, and as a rule areas are abandoned after two, three or four

Fig. 29.—A typical example of peasant banana-growing on one of the islands, Gatun Lake, Canal Zone. The Island was originally a hilltop, the soil is poor and plantations are accordingly short-lived.

crops—in fact, it is a typical example of shifting peasant cultivation. Near the occasional lime out-crops the soil is better so that some of the farms may last for seven years, and, I was informed, may give 70 per cent. of 9-hand bunches. In this region then we have a typical case where land has been abandoned, not on account of disease, but because of the rapid deterioration of indifferent soil in the absence of good husbandry.

As the launch proceeded up the Chagres River to Santa Rosa, a primitive settlement where some fruit is collected, localised banana plantations were observed on the hill-sides. The river was in flood at this time and it was observed that instead of carrying along heavy silt and sediment it was yellow with clay washings. This may be taken as an indication of the nature of the residual hill-side soil, depleted by long continued and extensive denudation of all its open friable materials.

Fig. 30.—A view on the Upper Chagres River, Canal Zone. The dead stumps of large trees indicate how the land has been flooded up by the formation of the dam. There is a considerable amount of banana cultivation along the new banks of the river, i.e., high ground not usually pressed into service when bottom lands, valleys, and lower hill slopes are available.

CONCLUDING OBSERVATIONS.

Although the data set out in this report are necessarily incomplete, yet certain broad generalisations emerge which are worthy of consideration:

(1) The old idea of the optimistic planter that all virgin soils are necessarily highly fertile must give way, after many costly misadventures, to a recognition of the fact that many areas are not suited to large scale exploitation. Where conditions have permitted of the latter the procedure has had the justification of financial success,

and large organisations, such as the United Fruit Company, have proved not only important agricultural pioneers, but also a great force in introducing and advancing civilisation. On the other hand, if the same methods are attempted in unsuitable areas, diseases and difficulties accumulate, and, sooner or later, abandonments result. These usually involve considerable capital loss. Thus it would appear that some areas, such as Stann Creek, Talamanca, and the Canal Zone are at present better suited to detailed selective cultivation by small private owners or a localised peasantry, than to the expensive and elaborate machinery involved in large scale exploitation.

(2) When new lands for large plantations were being sought out at the beginning of the modern banana industry, the great value of alluvial areas was soon recognised. Often the large tracts of country were very incompletely surveyed, thereby detracting from the general efficiency of field operations. One scheme of planting was used throughout, and on the whole the general botanical and agricultural knowledge brought to the task left much to be desired. Experience and detailed observation, however, have shown that alluvial plains have by no means uniform texture or fertility throughout. Some areas are so fertile that they appear to be able to support bananas almost indefinitely, but in close proximity other soils are found whose life, in the absence of detailed treatment, appears to be distinctly limited. The principle adopted in the early days to test the suitability of new areas was to fell the forest, plant and await the result. Failures on account of sourness, heavy clay, high water-table, poor soil, bad material, etc., were common, and the land was abandoned often without a second planting. Real insight into the problem was thus replaced by an expensive and destructive test. The justification of this procedure lay in the extensiveness of the field operations, and in the general success achieved, while agricultural and economic conditions were such that it was easier and cheaper to exploit new areas than to attempt to improve indifferent plantations by detailed treatment.

Thus, although large scale field operations have been in process for a quarter of a century or more, little has accrued to our general fund of agricultural knowledge from these sources. After a longer or shorter period of intensive single crop exploitation comes the inevitable abandonment. This may be due to deterioration or disease. The alluvial land is first used up and then there is a retreat to the untouched hillside areas, where the life of plantations usually proves to be of still shorter duration.

At the present time these are the usual pioneer phases in the agricultural development of new lands in Central America. It is perhaps the only method possible under existing conditions, and the procedure has many praiseworthy and justifiable attributes. At the same time giant forests are destroyed ; the native fertility of the soil is exploited to the utmost, and little or no effort is made to maintain or replenish it. But judgment of these matters is no easy task, and it must be left to the long arm of time to assign these agricultural methods to their proper category.

(3) These observations indicate the need for careful soil exploration, if failures due to choice of unsuitable land are to be reduced to a minimum. The variable nature of alluvial soils in certain large areas has been discussed at some length. Emphasis has been laid on the importance of studying river action where floods, changes in course, silt deposition, and erosion, are still operating vigorously. It has been shown that the resulting soil variations make for important differences in growth conditions in areas where uniform fertility might be expected. Detailed study of river action, then, may prove to be an important criterion in the selection of new land.

(4) To assess the importance of Panama Disease is now a task of the utmost difficulty. Where records are available, as in Jamaica, it is clear that the disease is by no means the most important limiting factor. In St. Lucia, where a banana industry collapsed, the failure has been attributed to insufficient finance. In Colombia, there is no record of Panama Disease yet considerable abandoned areas occur. In Central America, however, the problem is complex, and it is difficult to determine the importance of the several adverse factors which may be in operation at the same time. Causes of abandonment include :—

(*a*) Destruction by the activity and spread of the Panama Disease organism ;

(*b*) loss resulting from the use of diseased or defective planting material. There is a difference between this and the above ; this factor has an added significance in that, owing to the prestige of the disease, most areas where it had once occurred were never replanted ;

(*c*) adverse soil conditions, which include sourness, intractible sticky clay, high water-table, insufficient ventilation, and leaching of open soils;

(*d*) soil deterioration which sets in after four to seven years on poor soils, ten to fourteen years on medium soils, and twenty or more years on good soils, in the absence of good husbandry, rotation and detailed agricultural treatment ;

(*e*) poor production and bad upkeep due to general soil inferiority and undiagnosed factors.

Any of these alone or together may ultimately be the cause of abandonment. To the man in the street, however, " abandonment " in Central America and " Panama Disease " or " disease " are practically synonymous. The erroneous nature of this impression has frequently been pointed out in this report. That Panama Disease is very important cannot be doubted, but our knowledge is not being increased or a remedy brought nearer by overstatement or the propagation of misconceptions. In short, in any attempt to bring back abandoned areas into cultivation (other than by the use of an immune banana) there are clearly two distinct, but probably inter-related, aspects, namely the treatment of disease, and the recovery and maintenance of soil fertility.

(5) As these researches are directed ultimately towards economic ends, and as several different political interests are involved, it appears to the writer that there are many problems and issues worthy of the careful attention of a suitably equipped economist.

APPENDIX.

ST. LUCIA'S BANANA INDUSTRY*

BY

E. A. WALTERS, F.R.H.S., F.R.MET.SOC.,

Agricultural Superintendent, St. Lucia.

The purpose of the present paper is to provide a connected account of the inception and development of commercial banana planting in St. Lucia, with comments on the methods employed ([1]).

It is hoped in a future paper to give a description of the reactions of the soil and flora observed to take place in changing from a natural forest vegetation to a cultivated pure crop such as bananas, and the observations to be set forth therein will be found to have an important bearing on tropical agriculture in general. The present paper acts as an introduction to these observations.

The Gros Michel banana trade would be an attractive proposition were it not for the heavy losses suffered in conducting plantation work, when complicated by the presence of Panama Disease. The following information, based on the writer's actual participation in all phases of the industry, includes an account of the work done locally on Panama Disease and should assist in establishing the economic value of certain practices in connection with the attempted control of this disease.

Origin of Banana Industry.

St. Lucia, like other islands with a similar climate, had for some years previous to 1922, conducted a variable export trade in several varieties of bananas, chiefly the Short Fig or Governor banana, *Musa Cavendishii.* Paxt., the Bout Rond or Giant Fig and the Gros Michel or Martinique Fig. The principal market was Barbados, whence the fruit was shipped by sailing sloop.

Towards the end of 1922, a proposal for the development of large scale banana cultivation was received from the representative of certain fruit interests in the United Kingdom. This proposal was favourably received by the local Government and special facilities were granted, and an area of 200 acres of Crown land in forest was purchased by private interest vested in the Swift Banana Company, and the necessary steps were taken to enrol labourers for clearing and preparing the land.

The area acquired was situated about nine miles along the Castries-Dennery Main road and at an altitude of about 400 feet at a point where the forest reaches down to the road, the site was thus readily accessible.

The rainfall of this area averages about 100 inches yearly, and the soil when cleared from forest, is seen to be covered by a layer of decayed forest humus which readily desiccates on exposure. The soil itself is a yellowish-brown clay loam tapering off into hummocks of a red lateritic clay, and responds to careful cultivation. The contour of the land is of a rugged nature, consisting of steep ridges and folds enclosing narrow valleys with a few moderately smooth slopes.

---

* Reprinted by permission from " *Tropical Agriculture*," Vol. V, pp. 247–249 and 284–286.

The Commencement of Planting.

Preparations for planting commenced early in 1923 and consisted of felling the forest trees, some of which furnished useful building timber and roof shingles ; but the greater proportion of the fallen logs were left where they fell or merely moved aside to allow of planting. The herbaceous undergrowth was burnt or cutlassed down, and lining and holing was commenced. At this stage the local Agricultural Department was called in to assist, and remained in co-operation with the Banana Company until the work was brought to an end by the dissolution of the Company.

The planting material was collected from both the large and small surrounding planters' holdings and consisted of sword suckers and bullheads of Gros Michel stools, being paid for at the rate of three cents per bullhead. About 90,000 plants were thus established in an area of 15 acres by the end of 1923, the actual planting having been commenced about April of that year.

One of the first steps taken by the local Department was to inaugurate a system of inspection of all planting material, at this time principally directed against the banana weevil *Cosmopolites sordidus*, Germ., and the banana borer *Tomarus bituberculatus*, Beaud., as these root pests were being found in a rather large proportion of the material supplied for planting.

The bullheads and suckers were treated by clearing away the loose trash and broken leaf bases, and by paring the roots, the plants being then soaked in lime-water for 48 hours to destroy any concealed larvae and eggs.

Plants were spaced at a distance of 6 feet each way to form a nursery to give bulk of planting material ; when planted out in the fruiting areas the plants were spaced 12 feet by 12 feet.

The labour utilised throughout the work consisted of the local West Indian native, generally illiterate, and with crude ideas as to the value of disinfective and control methods, but a good mechanical worker. Both men and women were employed at the rate of 1*s*. 6*d*. and 10*d*. to 1*s*. per day respectively, at which rates ample labour was available.

Supervision was exercised by the more intelligent native overseers or " drivers," under the control of coloured assistants who were responsible to the European Manager.

Occurrence of Panama Disease.

The first three cases of Panama Disease were found in January, 1924, the plants infected being stools of about 7 to 8 months of age and situated on a slope in rather wet soil. The principal symptoms consisted of external yellowing of the lower leaves, and an internal yellowish-red discoloration of some of the vascular strands. In later cases where plants were more advanced in growth, splitting of the stem and some breaking of the petiole of the lowest leaf was observed, these latter symptoms, however, were never really pronounced nor general and were usually found in conjunction with borer and weevil attacks, i.e., severe dislocation of the food supply and ingress of bacteria to the vascular tissue. These symptoms differ somewhat from the published accounts, and will be discussed in the notes on soil conditions.

Measures taken against Panama Disease.

The measures taken to control further spread of the disease come under four headings :—

(i) Treatment of infected areas.

(ii) Improved selection of planting material.

(iii) Survey of the distribution of Panama Disease.

(iv) Propaganda.

(i) *Treatment of infected areas.*—In order to obtain the best advice possible, a visit of the Mycologist of the Imperial Department of Agriculture was arranged. Specimens of the diseased plants had already been submitted for examination and were reported on as showing characteristic symptoms of Panama Disease. The visit of the Mycologist took place in August, 1924, and an inspection of the area was made. A report was then furnished giving the precautions necessary to reduce infection, viz., (*a*) by firing the infected clumps and digging out and burning the diseased plants, and destroying the contacts within a radius of 22 yards, (*b*) by the disinfection of tools and the isolation of the infected areas.

The details of destruction of plants and disinfection were well adhered to and were generally carried out under the supervision of the Officers of the Agricultural Department.

The isolation of infected areas, however, was not complete owing to the difficult nature of the ground, and to the fact that the labourers did not regard the prohibited areas with the necessary respect.

(ii) *Improved selection of planting material.*—Selection of planting material was further improved by a method worked out by the writer, this consisted of the sectioning or quartering of the bullheads, which were then examined on both surfaces, and also on the top where the central bud had been sheared away. The sections were then dusted with wood-ash, and in some cases soaked in lime-water to destroy weevil and borer.

By this means it was found possible to reduce considerably the amount of infected planting material, and the method was adopted both in the plantations of the Swift Company and other banana cultivations which were springing up throughout the island, working in co-operation with the local Department.

The areas planted on this method were found to give an incidence of one diseased plant per 1,000 as against one per 100 in the unsectioned plants, the rate of spread was accordingly reduced and a longer life was possible for the fruiting plantations.

(iii) *Survey of Panama Disease, and legislative action.*—A survey of the distribution of Panama Disease throughout the Colony was made about this time, the results showing a scattered infection in practically all the estates on the leeward coast which are readily accessible and open to frequent traffic. On the windward coast little banana cultivation had been carried on in earlier times, and estates in this area showed but few Gros Michel and no cases of disease. One case of disease was found on an estate situated midway on a road running from coast to coast, indicating that Panama Disease was more widespread and of earlier origin than had at first been believed.

It thus became necessary to examine carefully every prospective banana cultivation, both with regard to the existing plants, and also to go into the history of the estates in order to determine whether Gros Michel had been planted in earlier times, and had

disappeared owing to Panama Disease. In this way much interesting information came to light, and the peasants were often of help in indicating that a " malade " of the Gros Michel had become a part of their traditions. A striking case of the replacement of the susceptible Gros Michel by an immune variety occurred on an estate near Castries, from which a regular fruit trade with Barbados had been maintained, the total absence of the valuable Gros Michel was therefore remarkable and on research it became evident that this variety had died out from disease, and had been replaced by the Bout Rond—a " round end " banana of a somewhat soapy consistency and of a less delicate flavour. This variety was later identified as similar to the Giant Fig of Grenada.

Following the completion of the survey of disease, regulations were enacted to enforce destruction of bananas infected with Panama Disease and the treatment of plants attacked by weevils and borers. The movement of planting material was also prohibited except by permit of the Agricultural Department, following an inspection of the estate in question.

The Department was allowed to train two men as travelling inspectors of banana cultivation, and these men rendered valuable assistance in recording outbreaks of disease, and by carrying out actual treatment of diseased plants. Altogether 28,831 diseased plants were treated during the period 1925 to 1928, mainly by the officers of the Agricultural Department. It may safely be said that the attitude of the peasantry has entirely changed owing to the educative effect of the inspection service, and the peasant now realises that disease is a condition brought about by some destructive organism and not the wilful act of a far-seeing Providence.

Information was obtained as to the total distribution of all banana crops and of projected crops. The diseases were noted, and the accessibility of land suited to bananas was recorded for future reference. This information has proved valuable both in regard to banana cultivation and to other crops which are being substituted for bananas.

(iv) *Propaganda.*—Planters and others were instructed in the symptoms of Panama Disease, the treatment of diseased plants, and the methods of planting. Meetings were held at various centres where specimens of plants were exhibited, and a leaflet, *The Control of Panama Disease,* was printed in simple language and distributed throughout the Colony ([2]).

Frequency of Panama Disease.

On checking up the information obtained on the survey a fairly definite idea was obtained of the frequency of cases of Panama Disease. Infection in the S.W. area of the Colony was at the rate of 0·7 per cent., and for the N.E. area was 2·5 per cent., whereas the lands of the Banana Company gave a range of 0·5 per cent. to 20 per cent. infection in the older areas.

Soil Conditions and Panama Disease.

Judging by the few published accounts dealing with soil conditions and Panama Disease, there appears to have been little work done on the types and conditions of soil in which Panama Disease flourishes, as compared with the types of soil where the fungus can be held in check, such as the irrigated lands of Jamaica and Columbia.

It is therefore of interest to record certain detailed observations with regard to the soil medium and the reaction of bananas to varying soil conditions. One of the most striking effects was noticeable in bananas planted towards the base of the slopes, these grew vigorously and produced good bunches, whereas plants on the tops of ridges showed dwarfing effects, yellowing of leaves, and produced only poor fruit. These exposed plants gave a poor rotation of fruiting stems and suffered from drought, brought about by the complementary factors of leaf splitting, an inferior type of soil, and irregular water supply.

On the other hand, the modifying action of windbreaks with the improved soil conditions found near by, was evidenced in the vigorous growth of the plant and the absence of leaf splitting, humus was conserved and little leaching appeared to take place.

The following observations deal with two distinct types of soil :—

(I) *Soil Conditions in the Nursery—Ravine Poisson.*

The soil here at the time of planting, might be termed a virgin soil, undisturbed by earlier cultivation and bearing large forest trees forming the closed tropical rain forest vegetation with a well developed canopy.

On removal of the timber by felling, and within 6 or 8 weeks a crop of soft weeds covered the ground forming a transition stage, preceding the establishment of the larger herbaceous plants.

The soil consisting of a brownish-yellow clay loam covered by a loose layer of forest humus about three inches deep, this covering had become matted by surface roots and was not well decayed. The soil when cut in profile showed as a smooth cheesy clay loam in which aeration appeared to be defective as depth increased, the upper six inches being somewhat improved in texture by decaying roots. The soil puddled readily when worked in wet weather but responded to aeration and applications of lime by changing in colour from brownish-yellow to brownish-grey, and by forming a definite crumb structure.

This type of soil under wet weather conditions became puddled and needed extensive drainage, in the lower areas the soil was never really dry and the bananas never suffered from drought.

During dry weather the soil cracked readily causing drought conditions, particularly along the ridges.

(II) *Soil Conditions on the Hill Slopes and New Areas—Mt. La Combe.*

Soil conditions in the new upper areas along the slopes of Mt. La Combe were notably different from conditions in the lower land and nursery.

The soil here had supported a similar forest vegetation to that already described, but when examined in profile showed a distinct stratification formed by a superficial layer of humus resting upon a bed of yellow clay, in which there appeared to be no admixture of the overlying organic matter. The soil was naturally stiff and difficult to work, readily becoming sticky in wet weather. Dry conditions were never observed owing to the continous seepage of surface water from the upper slopes.

This is a type of soil which must be worked, it requires extensive drainage and applications of lime, otherwise it deteriorates.

Root Conditions.

It is an interesting fact that the majority of the banana stools examined showed only a superficial root system.

Under soil conditions No. I the rhizomes were fairly deeply embedded in the soil, and possessed a few strong feeding and anchorage roots, most of these being in good condition.

Under soil conditions No. II the rhizome was less deeply embedded, and root penetration in the clay was remarkably poor. The feeding roots were scanty, and blackened for most of their length, and the absorbing rootlets appeared to die back at frequent intervals, whilst main roots had a water-soaked appearance.

In view of these defects it is a remarkable commentary on the vigour of the banana plant that bananas under these conditions gave much better returns than under soil conditions No. I, but it is doubtful whether plants could long survive such root reduction without serious loss of vigour and depreciation of bunches.

In utilising such primitive soil it should be a first charge that cultivation should be maintained and the physical conditions of the soil improved, as the small amount of available land restricts the grower to a limited area. This is in contrast to the methods employed in Central America where large areas of land are available ; in such conditions bananas are planted in holes opened through the cutlassed bush, and after taking the first few crops, these areas are abandoned for new ones planted on a similar method ([3]).

Disease Effects.

Plants infected with Panama Disease were in close contact with apparently healthy plants, which after a period of two years still exist and continue to fruit, although neglected, and it is interesting to note that recent observations show that many stools in close proximity to earlier sites of disease exhibit no symptoms of disease, and this after the wettest season for 10 years (June to November, 1927) followed by a short but severe drought (January to February, 1928). Such weather conditions are entirely in favour of a rapid extension of Panama Disease.

It was also noticed that Panama Disease appeared quite frequently as scattered cases, and not often as an extension from a central point ([5]). Further it should be mentioned that the external symptoms of Panama Disease showed certain differences from the published accounts.

A point which needs emphasising was the condition of the water-soaked lateral roots, where these had died back after penetrating a short distance into the soil. This condition was not confined to diseased plants.

Extension of Areas, Roads, and Transport.

A considerable impetus was given to banana cultivation as an estate crop, by the information given out by the Banana Company to the effect that banana contracts would be made with estate holders for a specified term to provide for the supply of Gros Michel of 7, 8 and 9-hand bunches at stated periods. As a matter of fact this form of contract was not regarded with favour by most planters, since the contract bound the planter to a five-year period during which time he should deliver his fruit only to the Swift Company. None of the contracts were therefore taken up and bananas were later collected by cash purchase at pre-arranged depots.

Bananas were established in several adjoining areas in the Cul-de-Sac and Roseau valleys, in all about 50 acres, which were being developed by local sugar interests. Development in other parts of the Colony was mainly evidenced by gradual extensions of the Gros Michel stools already present, particularly by small planters. An estate of 700 acres had been acquired by the Banana Company and was being rapidly converted from cacao to banana cultivation ; and by purchase of other land adjoining this property and the original cultivation, the whole area became linked up to form a continuous estate which was all to be planted up in bananas, mainly Gros Michel.

A system of roads was driven through this area to allow of motor transport, horse and donkey transport, and as highways for labourers. One ton Graham trucks were subsequently imported for the transport of bananas, the loading capacity being 100 bunches per trip. Meanwhile, the Agricultural Department continued to act in an advisory capacity, special stress being laid on the need for soil conservation. This included the provision of cover crops such as *Canavalia ensiformis*, the retention of belts of the existing forest to act as windbreaks, the extension of the drainage system by contour methods, and suggestions for pruning. With regard to pruning it was found that the average stool should consist of a fruiting stem about 11 to 13 months old—a large sucker about nine months old, to form the next bunch—and a medium sucker of three months, with two buds as followers.

This was the general character of work carried out through all the banana cultivations, in addition to the form of police-work entailed by the inspection service.

The Position of Panama Disease at the Time of the Fruit Shipments.

Panama Disease had in the meantime rendered the original nursery of the Banana Company unprofitable, and this area was accordingly abandoned ; planting continued vigorously in the new area consisting of a block of 5,000 acres of forest. These new forest lands gave very good bunches and continue to bear bananas to the present day. The cacao estate already mentioned gave very good returns during the first crop, but succumbed rapidly to Panama Disease during the second year of planting, and it became evident that the soil was thoroughly infected with the fungus, which had no doubt persisted from scattered clumps of Gros Michel used as a secondary crop in cacao.

Some of the affected areas were being replanted with Short Fig, Bout Rond, and the Apple banana (Fig Pomme) a variety somewhat similar to the Bout Rond but with a hard centre. This variety rapidly died out from Panama Disease, and little use was made of the other varieties for shipping purposes.

At the time of the regular fruit shipments, the total area under the control of the Company was about 6,000 acres of which about 1,800 acres had been planted up, and 250 acres had been thrown out of cultivation through the ravages of Panama Disease.

The Collection, Transport, and Shipment of Fruit.

The first shipment of fruit was made in 1925 to New York and was in the nature of a trial shipment, space being allotted for banana storage in ventilated holds. About 15,000 bunches of various grades were shipped from St. Lucia during this year in excess production over the normal export trade. Owing to the absence of regular fruit boats during this and the following year, much of the fruit was shipped by sloop to Barbados where a somewhat fluctuating market existed.

Definite shipping arrangements were made towards the end of 1926 and a chartered steamship, the *Kong Inge,* made her first shipment in November of that year, a crop of 4,673 bunches being loaded for New York where it passed into the hands of a prominent fruit company. The fruit was collected from the lands of the Banana Company, and from the various depots established throughout the island, where planters disposed of their fruit at the rate of 2*s*. 6*d*. per nine-hand bunch. This entailed a considerable amount of organisation, since time, and the condition of the fruit on delivery, was of major importance.

In all, four shipments of fruit were made by the *Kong Inge* during the next two months, a total of 24,422 bunches being exported. Then followed the unfortunate collapse of the industry due to the promoting Company becoming insolvent.

The total crop of the island at this time was officially estimated to be from 10,500 to 12,500 bunches per month, and this output could have been maintained from March to September of 1927, provided the cultivations continued to receive attention, this failing, the output fell off rapidly and much of the fruit was left to rot owing to the absence of shipping facilities.

Shipping Problems and Market Reports.

Bananas as shipped on the *Kong Inge* were stored in open holds but protected from the weather, the bunches being placed on end and kept in position by wooden gratings forming a series of sections through the holds.

The atmospheric conditions in the holds varied over a rather wide range as regards humidity, but temperature was fairly constant, as shown in the following details obtained by the recording instruments of the Department.—(*Ann. Rept.*, 1926.)

(1) *Range of Temperature and Humidity in the Banana Holds during the First Trip of the s.s. "Kong Inge,"* 10*th November*, 1926 *to* 17*th November*, 1926.

Fore-hold.			After-hold.	
Date.	Time.	Temperature. ° F.	Relative humidity. m.b.	Max. temperature. ° F.
Nov. 10	6 p.m.	75	70 (1)	— (1)
	12 p.m.	77	59	81
,, 11	12 a.m.	78	59	80
	12 p.m.	78	63	78
,, 12	12 a.m.	79	64	78
	12 p.m.	77	56	77
,, 13	12 a.m.	76	59	76
	12 p.m.	75	62	74
,, 14	12 a.m.	74	55	71
	12 p.m.	72	54	73
,, 15	12 a.m.	72	52	71
	12 p.m.	70	50	72
,, 16	12 a.m.	76	40	70
	12 p.m.	55	— (2)	55
	—	—	—	54 (3)

(2) *Conditions of Shipments of Bananas*, 1916–1927.

St. Lucia.	New York.	Temperatures in Holds. ° F. Max.	Min.	No. of bunches.	Condition on arrival.
10/11/26	17/11/26	80	40	4,673	Moderately ripe.
1/12/26	7/12/26	82	61	6,494	Not ripe.
22/12/26	29/12/26	79	54	7,349	Full ripe.
12/1/27	19/1/27	77	60	5,906	Moderately ripe.

([1]) Loading, open holds and heavy rain falling, departure at 7 p.m. with closed holds.
([2]) Holds opened on entering New York harbour.
([3]) Final reading with open holds and snow falling.

Under the conditions obtaining in these holds during a voyage of seven days, the fruit was not found to deteriorate unless bruised or over-ripe when shipped.

A shipment of fruit was subsequently made by a local Company formed to dispose of the marketable crop left on the lands of the Banana Company. In this instance the fruit was loaded into closed holds, supplied with forced ventilation by means of fans, after the manner of the modern cargo boat. Following a voyage of about 10 days, the fruit was discharged at New York in a more or less rotten condition. This was a case of decay being accelerated by long confinement in closed holds, from which the carbon di-oxide and the water vapour given off by the fruit, had not been adequately withdrawn.

This venture, therefore, met with no success and was discontinued. Trials of the Bout Rond banana already mentioned had been made previously in conjunction with Gros Michel shipments, but had met with no success, as this variety did not travel well owing to the naturally loose formation of the bunch, and to stem and finger rot to which the Bout Rond is susceptible.

Termination of Banana Activities and the Present State of the Plantations.

At the time of withdrawing the employed labour of the Banana Company, a considerable area of the cultivation contained untreated plants suffering from Panama Disease. The Agricultural Department was therefore required to carry out the destruction of these plants in order to reduce the amount of infective material, and to prevent the leakage of diseased plants from the abandoned estates.

There remained a large number of Gros Michel free from disease and bearing a crop, and the proceeds obtained from the sale of these bunches to local markets were utilised to defray the expenses of the sanitation work.

On the total withdrawal of supervision, and the non-treatment of new cases of infection arising from remaining stools, the position has markedly changed for the worse, and the writer's conclusion is that no further cultivation of Gros Michel on any but a transitory scale would be possible in St. Lucia under the present methods of large scale cultivation, which consist of nothing more than the attempted evasion

of the disease by reducing sources of infection, rather than the prevention of disease by utilising the soil type which is unfavourable to the spread of disease. There is in St. Lucia at present a sufficient amount of infective material to destroy any ordinary cultivation within a year or so, and any future banana development (in the absence of immune varieties) could consist only of the Short Fig or the Bout Rond, and both of these are unsuited for transport by sea with present methods.

At the present time the greater part of the banana land is covered by a vigorous growth of low bush and shrubs, in close association with excellent stools of Gros Michel which continue to thrive and produce 8 and 9-hand bunches.

Much useful knowledge was gained in the course of the five years' work on bananas, particularly in connection with the soil, and this has a definite value in the development of any other crop under similar conditions. The data collected will be discussed in a future paper on soil changes in relation to tropical agriculture.

With regard to the economic value of the original banana lands, a suggestion is here made that the best areas would serve admirably for coffee development, should any planter be sufficiently hardy to venture thereon.

From the above observations the writer ventures to suggest that more attention should be given to the soil conditions under which bananas thrive, as compared with soil conditions where bananas are largely subject to disease.

The writer wishes to acknowledge the generous assistance of Dr. C. W. Wardlaw, Ph.D., D.Sc., in commenting on the foregoing notes during his tour in St. Lucia as Pathologist appointed by the Empire Marketing Board to investigate Panama Disease.

Summary.

An account of the origin and growth of the Banana Industry in St. Lucia is given, reference being made to the co-operation of the local Agricultural Department with the developing Banana Company.

The occurrence of Panama Disease, the measures taken against the disease, particularly in selecting only the best planting material, and a survey of the distribution of Panama Disease throughout the Colony is discussed.

Soil conditions as affecting the general health of Gros Michel and variations in disease symptoms are noted.

The collection, shipment, and transport conditions are discussed, and certain suggestions as to future methods of research on Panama Disease based on habitat and ecological factors, conclude the paper.

Bibliography.

1. Walters, E. A.—Annual Reports of the Agricultural Department, St. Lucia, 1923 to 1927.
2. Walters, E. A.—The Control of Panama Disease (Leaflet).—Agricultural Department, St. Lucia, 1925.
3. Fawcett, W.—The Banana, its Cultivation, Distribution and Commercial Uses, 1913.
4. Hansford, C. G.—Panama Disease in Jamaica.—Micro-biological Circular No. 5.
5. Nowell, W.—Diseases of Crop Plants in the Lesser Antilles, 1923.
6. Russell, Sir J. *et al.*—Micro-organisms of the Soil, Rothamsted Monograph.
7. Hansford, C. G.—The Fusaria of Jamaica, Kew Bull. Misc. Inf. No. 7, 1926.

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE,
TRINIDAD.

29th April, 1929.

To the Empire Marketing Board.

Gentlemen,

I have pleasure in forwarding a report of my recent visit to the banana lands of the United Fruit Co., in Costa Rica, Panama, Colombia, and Jamaica.

It is to be regretted that neither Dr. Wardlaw nor I was able to visit the Fruit Company's Research Station at Tela, Honduras, where amongst interesting problems, the important question of the ripening of the Lacatan variety is engaging attention. There seems little doubt that in the search for an immune substitute for the Gros Michel, the Lacatan is the most suitable.

The determination of the precise set of conditions—temperature, humidity, concentration of storage gases, etc.—favourable to successful transport and the subsequent ripening to an attractive colour of a suitable, immune variety is possibly the main aim of the physiologist in the present Research Scheme. Nevertheless several interesting lines of work, to be carried out in close collaboration with my colleague, the pathologist, have suggested themselves in the course of these studies of the Banana in Caribbean plantations.

I have the honour to be, Gentlemen,

Yours respectfully,

LAURENCE P. McGUIRE.

PANAMA DISEASE OF BANANAS.

REPORT TO THE EMPIRE MARKETING BOARD ON A SCIENTIFIC VISIT TO THE BANANA PLANTATIONS OF COSTA RICA, PANAMA, COLOMBIA AND JAMAICA.

By Laurence P. McGuire, Ph.D., M.Sc., D.I.C.

INTRODUCTION.

THE following is a report on my recent visit to the banana properties of the United Fruit Company in Costa Rica, Almirante, Colombia and Jamaica.

It will be readily realised that the topography and geology, the climate and soils of these countries show so much variation from area to area that a detailed survey of the whole situation was impracticable. With the exception of the final operation—the actual ripening of the fruit at the port of destination—opportunities for reviewing the many aspects of the industry, commencing with the clearing of virgin forest, have presented themselves. The knowledge of orchard conditions, methods of handling, etc., will serve to direct research on lines applicable to the trade.

The visit, furthermore, has served the useful purpose of enabling one to assess, at value, the gross exaggerations concerning Panama Disease and abandonments. From hearsay alone, one would be led to believe that all wholesale abandonments had been due to a single factor—Panama Disease. This is far from true, and in many cases, as will be seen in the course of this report, this disease has been little more than an accessory cause.

The fact that the incidence of Panama Disease is, as a general rule, greatest in and invariably associated with soils of low fertility, or of obvious adverse conditions suggests strongly the influence of external factors on increased susceptibility ; on the other hand apparently good banana lands, we are told, were wiped out by Panama Disease, implying that Gros Michel, by virtue of its constitution is at all times, in all conditions of health and vigour, susceptible to the virulence of *Fusarium cubense*. Several possibilities are advanced, but as definite records on several points could not be obtained, one is not in a position to assess the correctness of these inferences.

I wish to take this opportunity of placing on record my appreciation of the hospitality shown me by the United Fruit Company, and their assistance to me in my investigations of banana problems. On all Fruit Company Steamers and railways the courtesy of free transportation was extended to me.

In acknowledging my indebtedness, I wish to include whole-heartedly members of the staff of the College. Mr. Geoffrey Evans, C.I.E., M.A., the Principal, has at all times shown a lively interest in all matters relevant to Banana Research: it is largely due to his forethought and action that this extensive and highly educational tour materialised. Professor Briton-Jones, who has had previous experience with Panama Disease and Professor Cheesman who for some time has been pursuing problems of the banana from the stand-point of cytology and genetics, have aided with generous discussion. The information thus afforded proved an exceedingly helpful introduction to the subject before I proceeded to banana cultivations in Central America. Such ready co-operation from members of the staff in the College and the facilities provided for research work there, are to play an important rôle in the attainment of the aims of the banana project of the Empire Marketing Board.

On my return I was able to discuss the situation fully with my colleague, Dr. Wardlaw. Though our visit to the Caribbean banana lands were made quite independently, we were, for the most part in decided agreement not only on banana problems but in matters of general economics and politics. His report is possibly the first to expose fearlessly the current exaggerations regarding Panama Disease and abandonments. Without intending to submit an encomium of him, I have not, for the purposes of due substantiation, hesitated to cite from my notes, points which have already been discussed by him in full.

COSTA RICA.

Banana cultivation in Costa Rica dates back approximately to the year 1880, but it was not until the year 1892 that the year's export reached a million bunches; in 1908 the ten million mark was reached and for several years approximately nine to ten million were exported annually. Of late there has been a decrease owing to the fact that large areas, originally under bananas, have been abandoned and replanted with cacao or converted into grazing lands.

(36265) F

The Banana estates of Costa Rica are so extensive and soil and climatic conditions so varied that one could not hope to make much more than a general survey in the short time allotted. One was able to visit the best farms and the worst, and a good deal of time was spent in abandoned areas.

In the Siquirres district, I visited one of the Fruit Company's best plantations, Monte Christi, which has been producing consistently excellently for the past twenty years. It was characterised by the uniformly-grown, tall, vigorous plants and a complete absence of gaps ; in between the rows there was very little undergrowth so that cleaning costs were reduced to a minimum. The soil was found to be a free, well-aired, well-drained, dark, sandy loam of good depth. In such a soil the roots, which had developed an abundance of healthy lateral rootlets, were found to have penetrated almost vertically downwards. It is not surprising that loss due to blow-down on this estate is practically negligible, since the texture of the soil is favourable to ready root penetration. This then gave one a clear conception of a very high grade—perhaps ideal—banana soil, which was extremely useful later as a standard of comparison. Another example of a uniformly grown vigorous plantation is the two year old Cedar Valley proposition which will be referred to again later.

In sharp contradistinction to the above was a plantation which the authorities were contemplating abandoning. The plants were smaller, less vigorous in their growth, the leaves rather yellow-green, and there were numerous gaps. The soil, on examination, was a badly aerated, poorly-drained, compact loam. The straggly root system was interesting indeed : root penetration in this soil was obviously difficult and was inclined to the horizontal rather than to the vertically downward growth mentioned above. The lateral roots were not white and turgid, but in many cases blackened and even dead. There was a considerable amount of Panama disease in this area. The above describes fitly the state of affairs frequently found in patches of poorly growing bananas in otherwise good plantations.

Numerous plantations were visited, examinations of the soil conditions made and various types intermediate between, and resembling the above, were encountered. In some of the better areas the naturally fertile soil is periodically enriched by the deposition of alluvium and thus high productivity has been maintained throughout

the history of such plantations, and in the absence of unforeseen circumstances, it may reasonably be hoped that these will continue to be excellent banana lands. Other areas, not so fortunately situated, are capable of producing well for the first few years, after which gradual degeneration follows. Under the present agricultural practice, these areas provide food for pessimistic speculation. The question of husbanding the natural resources of the soil is indeed serious, and has not received the prominence and attention due to it. Even a little treatment—breaking up of the soil for aeration, improvement of drainage, an occasional re-planting, the choice of a suitable rotation crop—would surely prove beneficial. Economic conditions are such that it is more profitable to exploit new lands than to improve the existing plantations.

During my stay, a number of abandoned areas were visited. Records of precise cause of abandonments were unfortunately not available. In addition to the ravages of Panama Disease, there are numerous other causes as will be readily appreciated after considering the following observations. One particular area, originally under bananas had been replanted with cacao and has since been abandoned. These trees produced practically nothing and were most unhealthy. Judging by the colour of the leaves, they were obviously suffering from acute chlorosis. This area, situated quite near Matina River, is badly flooded periodically. It is probable that the soil undergoes, at these times, a thorough leaching-out. Another area in which the Gros Michel had fared badly had been replanted with the Lacatan variety ; from their unhealthy condition it would appear that this area was a low grade banana soil. It should be mentioned that this area had been riddled with Panama Disease ; as the Lacatan has been definitely proved immune, conclusions may be drawn as to the part played by unfavourable conditions in facilitating the spread of disease.

Labour in the Latin-American republics is an extremely expensive item which is responsible for the reduction to the minimum cleaning, draining, operating and general upkeep.

On soils unsuitable for vigorous growth of the banana plant one invariably finds active competitive growth of secondary bush and grass necessitating more frequent cutlassing, which is reflected in the maintenance costs.

Again there are abandoned areas in which the lack of efficient drainage was clearly evident ; in both Costa Rica and Panama

compact loams are frequently met with and it seems the upkeep of main and lateral drains has been neglected presumably because production returns did not allow the expense of such operations. In short, failure to reflect the necessary margin of profit is the deciding factor in abandonment, and the chief causes of such failure are Panama disease, high maintenance costs and low productivity due to adverse soil conditions.

With regard to the incidence of Panama disease, it is said that there is not a single farm on which it does not occur to varying extents. As a general rule, cases were more numerous where plants were less vigorous. Cacao Farms in the Zent district present an interesting problem in this connection. Years ago these farms were completely wiped out by Panama disease and have since been converted chiefly into cacao lands. On examination of the soil, the usual adverse conditions, referred to above, were not in evidence and one would be inclined to regard this as good banana land on which vigorous growth would be assured. To what then was this failure to be ascribed? In the first place no results of detailed chemical analyses were obtainable—it is possible that such analyses would have offered a solution to the problem. In the second place when large areas were being opened up there was naturally a demand for large quantities of planting material, which was under the circumstances perhaps not so carefully selected: it is possible that diseased suckers were used and these lands infected in consequence. It is most unfortunate that no definite reliable information on the above two points can be obtained, since it would help us to answer an important question. Is *Fusarium cubense* so virulent a parasite that the Gros Michel plant, no matter how robust and vigorous, is susceptible? A substantially corroborated answer in the negative would infer that improvement of deteriorating soils would help to stem the invasion of Panama disease. In the present state of knowledge the question remains unanswered. Abandoned areas have been brought back successfully into banana cultivation, and it would be interesting to know how successful such a project would be on this plantation.

The two year old Cedar Valley banana plantation on a flat alluvial plain was another example of uniform growth of robust plants producing well. A few isolated cases of Panama disease were present. The precise nature of infection of one individual, surrounded by numerous healthy vigorous plants, is indeed an enigma!

Cases are numerous where plants surrounding a diseased stool have remained for years free of disease. In fact in no observed case had infection spread radially from a central point affecting neighbouring stools first.

I then proceeded to other lands in the Bananito district where the soil was very varied, consisting of river deposits with an admixture of varying percentages of clay washings from the hillsides. Several good banana areas were to be seen here. On a plot, near the river, the advantage of shovel cleaning was being tried out. The ground was shovelled clear of all weeds and grass which were heaped between the rows. Banana growth was vigorous and the production of good fruit was high, pointing to the beneficial effect of such cleaning. It should be pointed out, however, that the soil was naturally rich and drainage good. Despite the general vigorous growth, Panama disease was present.

Experimental plots in this district were visited: it should be mentioned that these are not under the supervision of the Fruit Company's Research Staff.

On a strip of water-logged soil on the farm Pleiades where the leaves had " yellowed " a plot of one acre was heavily pruned, the undergrowth cleared and drains cut with obviously good results.

In another area fertiliser experiments were in progress but up to that time no conclusions could be drawn.

A plot of one and a quarter acres which had been completely cleared, old stools dug up, and replanted in Colombian style, was being compared with an adjacent plot of the same size which was merely receiving the customary Costa Rican treatment. Records were kept of the number of marketable bunches from each plot. The replanted plot showed the greater number to date. Following on a visit from one of the Colombian employees, the experiment was undertaken merely to see whether increased profits would accrue from adopting the Colombian method of planting. It is a pity that a third plot, cleaned and old stools dug up, had not been replanted in Costa Rican style. Much light might have been shed on the value of replanting. The " digging out " in itself would make for conditions of improved aeration.

It should be explained that in the Colombian style of replanting, the base of the old parent (or " head "), together with three or four

suckers is removed *en bloc* and replanted ; in the Costa Rican, however, heads are dug up and chopped into " bits " weighing five to eight pounds, and containing at least three good suckers.

Abandoned lands in this district have been replanted with cacao or converted into grazing grounds, but it is interesting that some of these lands have again been converted into banana plantations with no small measure of success. The Red Banana has been cultivated on disease-riddled areas and has been found to succumb in many cases. Since this variety is normally extremely resistant, to what factors, presumably external, are we to ascribe this increased susceptibility ?

In addition to Panama disease, two further physiological banana troubles were encountered :—

(i) Leaf scorch in the Red Banana.

(ii) The Talia disease (named after the farm on which it was first reported). This appears to be a case of internal breakdown in the fruit itself, and I understand, without cutting open the fruit, its presence is detectable only in the mature fruit at an advanced stage. No organism has been isolated and little interest has been aroused on account of its infrequent occurrence and restricted distribution.

Records of chemical analyses of the soil in different areas were not available. The presence of adequate quantities of lime in the soil is regarded as having a deterrent action on Panama disease—the fact seems borne out by the relatively low occurrence of the disease in plantations near the rivers Reventazon and Barbillo, which flow through calcareous formations. However, other factors may account for this comparative freedom from disease.

In commenting on the backwardness of agriculture in Costa Rica and the absence of ordinary agricultural practices, a description of the method of opening up new areas is perhaps apposite. The new area is surveyed, the underbush cleared and stakes placed in rows. Holes fifteen inches in diameter and fifteen inches deep are dug at the stakes, and the planting material, or " bits " as they are called, are planted. The large trees are then cut down and after a while the young banana plants emerge through the mass of decaying branches, trunks, etc. No attempt at forking or stirring the soil is made ; the plant must make the best of the small hole in which it has been placed.

Summary of Visit to Costa Rica.—(1) The Banana propositions in Costa Rica are such that in the short space of time allotted for the visit, little more than a general survey could be effected.

(2) The expression " wholesale abandonment due to the ravages of Panama disease " needs modification. In the absence of definite records and information as to the precise reasons for abandonment, I submit that failure to reflect the necessary margin of profit has been the deciding factor and such failure has been due to one or more of the following :—

(*a*) Panama Disease.

(*b*) Low Production due to adverse soil conditions (poor aeration, poor drainage and water-soak, etc.), and lack of upkeep.

(*c*) High Maintenance Costs. These would be higher in poorer banana soils where competitive growth of secondary bush and grass is more active.

(3) Panama disease is indeed widespread and it is stated there is hardly a farm on which it does not occur to varying extents. In no observed case had infection spread radially from a central point affecting the adjacent stools first. Why apparently good banana soils have been ravaged with Panama Disease is in the present stage of knowledge unanswerable and one can but offer theories. Definite records of the history and development of individual farms, of the sources of planting material, especially when large areas were being pressed into service, and of detailed chemical analyses of soil samples are entirely non-existent.

(4) Banana cultivation in Costa Rica implies merely the utilisation of the natural fertility of the soil ; it is feared the extremely high cost of labour will postpone the day of detailed agricultural practices.

PANAMA DIVISION.

Large scale banana operations in the Panama division commenced approximately 30 years ago and were centred around Almirante in Northern Panama. Of late years consequent on the scarcity of fruit and the necessity for exploitation of new areas, banana lands were opened up in the Canal Zone, while the Chiriqui division on the Pacific side of the Isthmus is now in course of being established. The two newer divisions were not included in my itinerary : my remarks are therefore confined to my visit to the Almirante Division,

which consists of three districts, viz., the Changuinola, the Sixaola (named after the two large rivers) and a newer extension, the Talamanca. I was able to see very little of the last named owing to a wash-away. It should be mentioned that the cost of upkeep of railroad tracks and bridges is exceptionally high owing to the torrential nature of the seasonal inundations to which this country is subjected.

Panama disease was first reported in 1903, and during the last ten years abandonments have been necessitated to an amazing extent. To the man in the street this is, of course, all due to Panama disease. From a consideration of the following it will be realised that, as in Costa Rica, several contributory causes have played equally prominent parts. Definite information on many questions of past history, etc., were very difficult to obtain. It appears that most of these areas produced well at the start and for several years high production was maintained. While Panama disease was reported early in the history of these farms, it was not until the later years that rapid spread was recorded. In other words, while the soil was sufficiently rich to allow of vigorous growth and high production, the spread was often very slow; later when the soil had degenerated and less vigorous growth was possible, the spread is reported as having been appreciably more rapid. Again, therefore, one's attention is drawn to the impoverishing influence of a continuous single crop on virgin soils. Some soils have continued to produce good fruit consistently over a long period, while others, after five, ten or fifteen years, in the absence of any attempt at conserving the natural fertility of these soils by ordinary agricultural treatment, have deteriorated to an extent that has rendered further maintenance unprofitable.

In considering the natural spread of the disease there seems little doubt that during extensive expansion with consequent demand for large quantities of planting material, diseased suckers were used. Again too, in this rush, the survey of proposed new banana lands could not be undertaken with sufficient attention to detail: in consequence land totally unfit for banana cultivation was pressed into service. An abandoned area which had been replanted with the Lacatan variety bears ample testimony. Growth was extraordinarily backward, and on examination of the soil it was found that below a shallow surface soil of some six inches of compact loam, there was a layer of thick sticky yellow clay of low permeability, in which root penetration would be difficult and drainage obviously poor.

My chief interest in the Panama division was Farm 6 in the Changuinola district, where I spent most of the time with the Fruit Company's geneticist. On this farm a large collection of banana and plantain varieties has been made with a view to breeding an immune hybrid to replace the Gros Michel. (Full descriptions of these varieties are already in print so that they will not be discussed in this report.) A tremendous amount of work has been done here, but unfortunately, owing to the prevalence of Panama disease, the Gros Michel cannot be used as either staminal or ovarial parent. In consequence, varieties, which of themselves have but few desirable characters, have perforce to be used as parents. Up to the present no hybrid of commercial value has been obtained.

The stay here was extremely important as one had an opportunity for studying these varieties growing under comparatively similar conditions. One of the chief aims of the present research scheme, from the Physiologist's point of view, is the choice of a suitable substitute for the Gros Michel, after which research will be conducted with a view to ascertaining the precise set of conditions under which transport and subsequent ripening up to an attractive colour can be effected. The more nearly these conditions approximate to Gros Michel conditions the better are the chances of persuading the trade to take up the new variety. There seems but one variety about which optimistic views may be entertained, viz., the Lacatan. Ripening experiments with this variety are now in progress at Tela. I understand this fruit has, on occasions, ripened satisfactorily, so that in course of time this problem will no doubt be solved. The Lacatan is a banana of good bunch habit, excellent flavour and delicate texture. It would, however, require far more attention in the field.

The general regularity of the bunch is often interfered with by the lower leaf on the side next the bunch. As the bunch develops, this leaf is held between successive " hands," and often in the reaping bad bruising results. In the Gros Michel this leaf is not persistent. It may be observed growing between successive hands while the bunch is still very young, but with advancing maturity this leaf withers and falls away. Many varieties are like the Lacatan in this respect. The Lacatan is, moreover, not inclined to deep rooting so that in areas where conditions militate against root penetration this variety would be very subject to blow down. The weight of the bunch was frequently perceived to have pulled down the whole plant which was either completely uprooted or its trunk snapped off at ground level.

This collection of banana, plantain, and abaca varieties has been derived from more or less world-wide sources : in most cases they have grown far more vigorously and borne bunches of greater size (more numerous " hands " and larger " fingers ") than in their original haunts. So that this area is to be regarded as good banana land. In this highly infected soil, in which naturally the chances of infection are correspondingly high, the behaviour of the highly susceptible varieties, e.g., Gros Michel and indio-plantain, which are usually extremely short-lived, when compared with the behaviour of the highly resistant and immune varieties, stresses the importance of inherent constitutional characteristics in the matter of resistance and immunity.

Abandoned areas have, as a general rule, been replanted with cacao or coconuts or turned into grazing lands. The cacao has so far not come up to expectations, while the coconuts cannot be regarded as successful. In general, growth is poor and they are subject to various troubles. About 4,000 acres of Lacatan have been planted, but these are not being exported in any quantity yet. In passing through the plantations, the irregularity of growth and the great variability of the soil are striking. The Changuinola and Sixaola districts may be described as extensive, for the most part flat alluvial plains which have been laid down by large rivers, which have repeatedly changed their course. Leaching by periodical flooding and high rainfall has contributed further to the general variability. These plains are frequently interrupted by rivers, creeks, lagoons, swamps, etc. Bananas growing near these swamps exhibit in general the effects of water-soak, which has no doubt been responsible for poor productivity and subsequent abandonment of large areas.

On another area, production was reported as having been good for four or five years, after which a progressive falling-off set in culminating in abandonment. In the later years Panama disease had spread rapidly and, of course, is put down as the cause of abandonment. Nevertheless, examination of soil conditions at several points reveals numerous adverse conditions : the surface was shallow and compact, below which was a deep impervious sub-soil of sticky clay in which root penetration would be difficult, and drainage and ventilation quite inadequate.

My visit to the Almirante division may be summarised thus :—

(i) Attention is again drawn to the deterioration of virgin soils under a continuous single crop, when the ordinary methods of agricultural treatment, for purposes of conserving original fertility, are not practised.

(ii) Careful analysis of the position shows that there are numerous factors in addition to Panama disease, to which abandonment may be attributed.

(iii) In general the spread of Panama disease was slow in the early history of plantations when virgin conditions made for vigorous growth of the Gros Michel.

(iv) An opportunity was taken of comparing the bunch habit of numerous varieties of bananas. In the search for an immune variety as a substitute for the Gros Michel, the Lacatan seems most suitable.

(v) The extraordinarily vigorous growth and high productivity of the numerous imported resistant varieties in badly infected soil stresses the importance of inherent constitutional characteristics in questions of resistance and immunity to Panama disease.

COLOMBIA.

Records show that Bananas were first exported from Colombia in 1892. In 1911 nearly five million bunches were shipped and in 1926 the ten million mark was reached. Last year, despite the strike among Fruit Company labourers, it was estimated that this figure would be reached.

Colombia is full of interest to any one engaged in investigating Banana problems on several grounds :—

(i) No occurrence of Panama disease has yet been reported there. The study of the effects of water-soak, lack of aeration and general adverse factors responsible for abandonment, is thus facilitated.

(ii) Owing to low rainfall and seasonal dry periods irrigation is necessary. The study of the water relations of the banana plant is suggested as a line of work in connection with Panama disease.

The banana lands of the Santa Marta division consist of a large coastal plain deposited by several parallel rivers, chiefly the Rio Frio, Sevilla and Aracataca, which rise in the Sierra Nevada. These

soils exhibit considerable variability and it was interesting to note that the Gros Michel was established, and thriving, on numerous types of soil varying from coarse sands to fine clay loams.

Despite the absence of Panama disease large areas have been abandoned. In the Rio Frio district, near the sea, large areas have been abandoned on account of " salting up." These are low-lying areas and, at present, the only vegetation consists of leathery-leaved xerophytes and the samphire, a remarkably reliable plant indicator which thrives only on soils of high saline content. Examination of the surface soil shows a large percentage of soluble crystalline matter which has not been leached out owing to the inadequacy of the supply of irrigation water and the high evaporation in these parts.

On large areas where the soil is of open coarse texture the Gros Michel plantations are of a high standard of excellence ; so long as an adequate supply of irrigation water is available, particularly in the dry periods, the high productivity of these plantations seems assured. There are, on the other hand, areas in which conditions do not make for good drainage and proper soil aeration. Examination of the soil has frequently revealed the presence of a deep stratum of blue, or blue mottled with red, clay, below a shallow surface soil of perhaps nine to twelve inches deep.

In planting up this land, the customary fifteen inch hole is dug at intervals of eleven feet by eleven feet, so that from the beginning the rooting system is in contact with this impervious layer of clay. The toxic action of such layer is clearly evident in the blackened (often killed) flaccid rootlets and the general stunting of growth. I understand it is not unusual, in these circumstances, for the plant to take as long as eighteen to twenty months, instead of about twelve months, to produce fruit suitable for harvesting. General preparation of these areas before planting with a view to improved ventilation would most probably go hand-in-hand with increased productivity.

The effect of water soak—an important cause of abandonment in Colombia—may be studied the more easily as graduations from the thoroughly water-logged to the well-drained, open condition can be found within comparatively small areas. One particular case in which bananas were growing in and on the sides of a water-logged depression was striking indeed. As one walked down the incline there was a progressive stunting of growth of the whole plant and an increasing paling of the greenness of the leaves to a yellow condition.

It is interesting that in many cases, especially where the underlying adverse factor is obvious, reclamation of abandoned areas has been possible. In the case of water-logged areas, deep main and lateral drains have been mechanically cut by means of the drag-line and the water table lowered in this way.

A most serious source of loss in Colombia is the " blow down." Wind-storms arising in the hills sweep down the plains and cause severe losses. Total uprooting of the whole plant is, despite the fury of these storms, by no means the general rule, especially where soil conditions are favourable to deep root penetration. In Jamaica, pruning operations are carried out in such a way that over 90 per cent. of the year's fruit is reaped before the " blow " season. Replanting operations, too, are timed with this object in view.

The attractiveness of the fruit is often interfered with by the activities of the Banana beetle (*Colaspis hypochlora*, Lefevre, 1878), which has been nicknamed the " Chinese Secretary " on account of its weird markings, suggesting Chinese characters, which it makes on the skin of the fruit. It does not, however, completely puncture the skin of the fruit as does the Banana Bee (*Trigona amalthea*, Oliv.) which in this respect is more serious. These insects are engaging the attention of the Fruit Company's entomologist.

While in Colombia, I had the good fortune to meet Dr. A. O. Reinking and Mr. Slocum of the Company's Research Staff. I had, therefore, an opportunity of discussing with them various banana problems and proposed lines of work. I am indebted to both of them for much sound information.

Summary.—(i) Colombia occupies a unique position among the world's banana producing countries in that, at no time, has Panama disease ever been reported.

(ii) The chief causes of abandonment have been poor drainage, poor aeration, " salting up " and inadequacy of supply of irrigation water.

(iii) A most serious cause of loss yearly is the " blow down " due to wind storms arising in the hills.

(iv) Owing to low rainfall and seasonal dry periods, irrigation is compulsory.

JAMAICA.

The visit to Jamaica was not originally included in my itinerary. In view of the Colombian strike, the Elders and Fyffes boats, normally due to call at Santa Marta, were being diverted. Instead of making a prolonged stay in Colombia, which this would have involved, I was able, through the courtesy of Mr. Bradshaw, the Manager of the Santa Marta Division, to proceed to Jamaica to meet the boat. I was thus afforded an opportunity for reviewing the situation there. I should mention that Mr. Hartley Rowe, one of the Vice Presidents of the Company, who was in Jamaica in connection with the purchase of the Lindo Estates, very kindly authorised my visiting the Research Division in Honduras. As several matters concerning our cold storage station required my personal attention, my immediate return was deemed advisable. It is to be regretted that neither Dr. Wardlaw nor I was able to make this important visit.

The banana producing centres of Jamaica may be roughly classified into two :—

In the South Eastern and South around St. Catherine and Vere are large flats, where rainfall is restricted (approximately 30 inches and 20 inches respectively), and irrigation is necessary ; in sharp contrast, the hilly districts of Portland, of considerably higher rainfall (130 inches approximately), do not require irrigation. In the former there is considerably less Panama disease, suggesting again the possible importance of a study of the water relations of the banana plant as an avenue of approach to successful results in Panama disease Research.

Examination of the soil conditions, texture, drainage, aeration, etc., in these areas stresses the influence of external conditions in the spread of the disease ; it further points out the extremely wide range of soils on which the banana may be profitably cultivated. Two particular farms were strikingly interesting in this respect. In one the surface soil could be described as a seam, at least four feet deep, of coarse sand or fine gravel, and the other was a sandy soil containing as much as thirty per cent. of limestone, chiefly in small lumps. I was told that these farms were regarded as producing up to the average, though naturally the supply of irrigation water was high. An interesting attempt at growing bananas on a neutral soil of sixty per cent. clay of low permeability was in progress. Drains four feet six inches deep, were cut for every two rows of bananas

so that each row was marginal on a drain. At the time of my visit the plants looked comparatively healthy. Unfortunately, however, the upkeep was expensive, apart from damage done to the roots by the cracking of the clay. As there are large areas of this type of soil available, the question of introducing clay-tile drainage on a small experimental plot is being considered, though it is realised that initial costs would be high. Good production, if maintained over a number of years, would justify the venture.

I was able, on two occasions, to accompany Dr. Klevenger, the Fruit Company's soil expert, who had come to Jamaica to carry out reconnaissance expeditions on the lands, newly acquired under the purchase of the Lindo Estates.

As Fawcett in his book "The Banana," describes in detail the intensive cultivation, land preparation, rotation crop, irrigation and contour drainage and the many aspects of the Jamaican Banana industry repetition seems unnecessary here. Furthermore, I shall not discuss the present quarantine regulations and the nine-root treatment in Jamaica as my colleague has dealt with the matter at length.

SUMMARY AND CONCLUSIONS.

While the shortness of the time allotted for the visits to the banana producing countries has precluded detailed survey of the whole situation, it is, nevertheless, possible to generalise on several interesting points.

Agriculture in the Central American republics is still a process of exploitation of the natural resources of the soil: no detailed agricultural methods are practised. On certain alluvial areas, particularly those enriched with a periodical deposition of silt, high production has been maintained over a considerable number of years, but on others this has been far from the case. In short the soil, under a continuous single crop in the absence of any attempt to conserve natural fertility, seems to have undergone, with consequent fall in production, a progressive deterioration towards the inevitable abandonment.

The high cost of labour has made it more profitable to exploit new areas rather than improve the existing farms. With the march of time, however, economic conditions may turn the scales so that

reclamation of the abandoned areas will be preferable to the acquisition of new lands. Abandoned lands have already been replanted with success.

In the rush to open up new lands it is possible that the survey was not always carried out sufficiently carefully, with the result that lands quite unsuited to bananas were pressed into service: the prevailing assumption that virgin soil is, of necessity, always fertile is quite unwarranted—a fact borne out by irregularity of growth, even within small areas of newly opened land, where due care has been taken in the selection of vigorous planting material.

Examinations of soil profiles in both abandoned lands and in bad patches in otherwise good plantations often reveal a surface soil of varying compactness under which is a stratum of sticky clay of low permeability, in which root penetration is difficult. Water-logging and poor aeration have obviously militated against successful growth and production to an extent that has necessitated abandonment.

Enough has been said to disprove the current erroneous views regarding Panama disease in abandonment. It has undoubtedly been most important, but in many cases it has been only an accessory factor. Large areas have been abandoned in Colombia where Panama disease has not yet been recorded; in view of this, the importance of other factors which we may describe broadly as adverse factors, may be more readily appreciated. These include :—

(*a*) Progressive deterioration of soils, once suitable for vigorous growth.

(*b*) Adverse soil conditions, several of which are, to a certain extent, inter-related, e.g., poor drainage, defective aeration, impermeability and/or toxicity of sub-soil, shallowness and/or compactness of surface soil, high acidity, high salinity, inadequacy of water supply for irrigation, leaching out by floods or high rainfall.

(*c*) Lack of upkeep. Where adverse conditions prevent vigorous growth in the banana, competitive growth of secondary bush, grass, etc., is increased and is reflected in increased cleaning costs.

Any of these factors individually or collectively may cause abandonment.

Panama disease is reported to have spread most rapidly in areas where adverse soil conditions militate against healthy vigorous growth ; on the other hand, resistant and immune varieties planted on highly infected soils have shown remarkable vigour. We have thus support for two views, which in the light of present knowledge, appear conflicting. The former suggests that the Gros Michel, in the state of low vitality induced by unfavourable conditions is then unable to check the invasion of *Fusarium cubense ;* the latter implies that at all times, in all conditions of soil and in all conditions of health and vigour, the Gros Michel by virtue of inherent constitutional characteristics is susceptible to the virulent invader. There is much to be said in support of both views.

" Blow-down " in the windy season is a source of considerable damage. In Jamaica, planting (and replanting) and pruning operations are timed to ensure that over ninety per cent. of the year's crop is reaped before the windy season (August–October).

In the course of this report I have refrained from discussing the strike in Colombia, or expressing any views of the political situation there, or in any other Central American republics. Political interests and the wide field for economic study merit the attention of a suitably trained economist.

PUBLICATIONS OF THE EMPIRE MARKETING BOARD.

E.M.B.1.	AGRICULTURAL ECONOMICS IN THE EMPIRE. Report of a Committee appointed by the Empire Marketing Board	6*d.*	(7*d.*)
E.M.B.2.	TROPICAL AGRICULTURAL RESEARCH IN THE EMPIRE with special reference to Cacao, Sugar Cane, Cotton and Palms. By C. A. Barber, Sc.D., C.I.E.	1*s.* 6*d.*	(1*s.* 8*d.*)
	REPORTS ON DEVELOPMENT OF AGRICULTURE IN CERTAIN COLONIES. By H. C. Sampson, C.I.E., Royal Botanic Gardens, Kew :—		
E.M.B.3.	Trinidad	3*d.*	(4*d.*)
E.M.B.4.	British Guiana	9*d.*	(10*d.*)
E.M.B.5.	Leeward and Windward Islands and Barbados	6*d.*	(7*d.*)
E.M.B.6.	GEOPHYSICAL SURVEYING. Report of a Sub-Committee of the Committee of Civil Research	6*d.*	(7*d.*)
E.M.B.7.	THE CHEMISTRY OF WINE MAKING. A Report on Oenological Research. By J. T. Hewitt, M.A., D.Sc., Ph.D., F.R.S..	1*s.* 0*d.*	(1*s.* 2*d.*)
E.M.B.8.	GRASS AND FODDER CROP CONSERVATION IN TRANSPORTABLE FORM. Memorandum by A. N. Duckham, B.A., Dip. Agric. (Cantab.), Rowett Research Institute, Aberdeen	1*s.* 0*d.*	(1*s.* 2*d.*)
E.M.B.9.	EMPIRE MARKETING BOARD, MAY 1927 TO MAY 1928	1*s.* 0*d.*	(1*s.* 2*d.*)
E.M.B.10.	EMPIRE GROWN SISAL and its importance to the Cordage Manufacturer : Memorandum prepared by the Imperial Institute with the co-operation of its Advisory Committee on Vegetable Fibres	6*d.*	(8*d.*)
E.M.B.11.	VITICULTURAL RESEARCH. Memorandum by D. Akenhead, M.A., B.Sc.	1*s.* 0*d.*	(1*s.* 2*d.*)
E.M.B.12.	REPORT ON INSECT INFESTATION OF DRIED FRUIT. By J. G. Myers, Sc.D., M.Sc., F.E.S., Imperial Bureau of Entomology..	1*s.* 0*d.*	(1*s.* 2*d.*)

[*Continued.*

Publications of the Empire Marketing Board—(*continued*).

E.M.B.13.	Grape Fruit Culture in the West Indies and British Honduras. By Professor H. Clark Powell, B.Sc., Professor of Horticulture, Transvaal University College, Pretoria	1*s*. 0*d*.	(1*s*. 2*d*.)
E.M.B.14.	The Survey Method of Research in Farm Economics. Memorandum by J. P. Maxton, M.A., B.Sc., Agricultural Economics Research Institute, Oxford.	0*s*. 6*d*.	(0*s*. 7*d*.)
E.M.B.15.	Oranges, World Production & Trade. Memorandum prepared in the Statistics & Intelligence Branch of the Empire Marketing Board.	1*s*. 0*d*.	(1*s*. 2*d*.)
E.M.B.16.	Report on Development of Agriculture in British Honduras. By H. C. Sampson, C.I.E., Royal Botanic Gardens, Kew. ..	1*s*. 6*d*.	(1*s*. 8*d*.)
E.M.B.17.	Schistosomiasis and Malaria in Relation to Irrigation. By J. F. C. Hasiam, M.C., M.D., M.R.C.P.Ed., D.P.H., Director of Library Services, London School of Hygiene and Tropical Medicine; Assistant Director, Bureau of Hygiene and Tropical Diseases.	1*s*. 3*d*.	(1*s*. 5*d*.)
E.M.B.18.	The Composition of Pastures. By J. B. Orr, D.S.O., M.C., M.A., M.D., D.Sc., Director of the Rowett Research Institute, Aberdeen	9*d*.	(10*d*.)
E.M.B.19.	Empire Marketing Board, May 1928 to May 1929	1*s*. 0*d*.	(1*s*. 2*d*.)

All prices are net; those in parentheses include postage.

Obtainable from the sale offices of

HIS MAJESTY'S STATIONERY OFFICE

LONDON: Adastral House, Kingsway, W.C.2. EDINBURGH: 120, George Street.
MANCHESTER: York Street. CARDIFF: 1, St. Andrew's Crescent.
BELFAST: 15, Donegall Square West.
Or through any Bookseller.

PANAMA DISEASE OF BANANAS.

REPORTS ON SCIENTIFIC VISITS TO THE BANANA GROWING COUNTRIES OF THE WEST INDIES, CENTRAL AND SOUTH AMERICA

By

CLAUDE W. WARDLAW, Ph.D., D.Sc., F.R.S.E.
Pathologist for Banana Research at the Imperial College of Tropical Agriculture, Trinidad,

and

LAURENCE P. McGUIRE, Ph.D., M.Sc., D.I.C.
Physiologist for Banana Research at the Imperial College of Tropical Agriculture, Trinidad.

E·M·B

JULY, 1929

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
Price 1s. 6d. Net.

PUBLICATIONS OF THE EMPIRE MARKETING BOARD.

Single copies of the following publications may be obtained, free of cost, on application to THE SECRETARY, EMPIRE MARKETING BOARD, 2, QUEEN ANNE'S GATE BUILDINGS, LONDON, S.W.1.

Leaflets :

- The Empire Marketing Board—a brief description of the Board's Work.
- The Empire Marketing Board and the Home Producer.
- Why should We Buy from the Empire ?

Booklets :

- A Calendar of the Fruits and Vegetables of Empire.
- A Book of Empire Dinners.
- A List of Empire Tobaccos.